9

LEVEL II

12

DOT/FAA/RD-81/56

# Discrete Address Beacon System Data Link Capacity Requirements


Dr. Anand D. Mundra
The MITRE Corporation
1820 Dolley Madison Boulevard
McLean, VA 22102





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Final Report





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16. Abstract


The Federal Aviation Administration ~~(FAA)~~ plans to deploy the Discrete Address Beacon System (DABS) as a key feature of its upgraded third generation Air Traffic Control ~~(ATC)~~ System. DABS provides an integral data link capable of conducting rapid transfer of data between the sensor and DABS equipped aircraft. This study establishes the performance requirements of the DABS data link to be able to provide the various services that may reasonably be expected to be delivered by DABS durings its life time.


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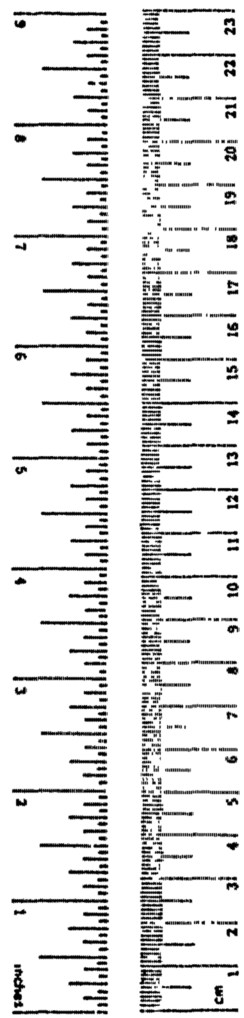
# METRIC CONVERSION FACTORS

## Approximate Conversions to Metric Measures

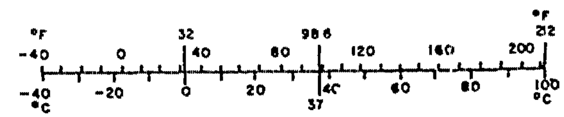
| Symbol | When You Know | Multiply by | To Find | Symbol |
|---|---|---|---|---|
| | **LENGTH** | | | |
| in | inches | *2.5 | centimeters | cm |
| ft | feet | 30 | centimeters | cm |
| yd | yards | 0.9 | meters | m |
| mi | miles | 1.6 | kilometers | km |
| | **AREA** | | | |
| $in^2$ | square inches | 6.5 | square centimeters | $cm^2$ |
| $ft^2$ | square feet | 0.09 | square meters | $m^2$ |
| $yd^2$ | square yards | 0.8 | square meters | $m^2$ |
| $mi^2$ | square miles | 2.6 | square kilometers | $km^2$ |
| | acres | 0.4 | hectares | ha |
| | **MASS (weight)** | | | |
| oz | ounces | 28 | grams | g |
| lb | pounds | 0.45 | kilograms | kg |
| | short tons (2000 lb) | 0.9 | tonnes | t |
| | **VOLUME** | | | |
| tsp | teaspoons | 5 | milliliters | ml |
| Tbsp | tablespoons | 15 | milliliters | ml |
| fl oz | fluid ounces | 30 | milliliters | ml |
| c | cups | 0.24 | liters | l |
| pt | pints | 0.47 | liters | l |
| qt | quarts | 0.95 | liters | l |
| gal | gallons | 3.8 | liters | l |
| $ft^3$ | cubic feet | 0.03 | cubic meters | $m^3$ |
| $yd^3$ | cubic yards | 0.76 | cubic meters | $m^3$ |
| | **TEMPERATURE (exact)** | | | |
| °F | Fahrenheit temperature | 5/9 (after subtracting 32) | Celsius temperature | °C |

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.




## Approximate Conversions from Metric Measures

| Symbol | When You Know | Multiply by | To Find | Symbol |
|---|---|---|---|---|
| | **LENGTH** | | | |
| mm | millimeters | 0.04 | inches | in |
| cm | centimeters | 0.4 | inches | in |
| m | meters | 3.3 | feet | ft |
| m | meters | 1.1 | yards | yd |
| km | kilometers | 0.6 | miles | mi |
| | **AREA** | | | |
| $cm^2$ | square centimeters | 0.16 | square inches | $in^2$ |
| $m^2$ | square meters | 1.2 | square yards | $yd^2$ |
| $km^2$ | square kilometers | 0.4 | square miles | $mi^2$ |
| ha | hectares (10,000 $m^2$) | 2.5 | acres | |
| | **MASS (weight)** | | | |
| g | grams | 0.035 | ounces | oz |
| kg | kilograms | 2.2 | pound | lb |
| t | tonnes (1000 kg) | 1.1 | short tons | |
| | **VOLUME** | | | |
| ml | milliliters | 0.03 | fluid ounces | fl oz |
| l | liters | 2.1 | pints | pt |
| l | liters | 1.06 | quarts | qt |
| l | liters | 0.26 | gallons | gal |
| $m^3$ | cubic meters | 35 | cubic feet | $ft^3$ |
| $m^3$ | cubic meters | 1.3 | cubic yards | $yd^3$ |
| | **TEMPERATURE (exact)** | | | |
| °C | Celsius temperature | 9/5 (then add 32) | Fahrenheit temperature | °F |



## EXECUTIVE SUMMARY

The Federal Aviation Administration (FAA) plans to deploy the Discrete Address Beacon System (DABS) as a key feature of its upgraded third generation Air Traffic Control (ATC) system. DABS provides significant improvement over the current Air Traffic Control Radar Beacon System (ATCRBS) in its surveillance function. In addition, it provides an integral data link capable of conducting rapid transfer of data between the sensor and DABS equipped aircraft. This study establishes the performance requirements on the DABS data link to be able to provide the various services that may reasonably be expected to be delivered by DABS during its lifetime.

### Expected Services

The study assumes that the following set of services will become available for delivery via the DABS data link within ten years of DABS deployment. These services include all the services considered by the FAA DABS data link program for near term implementation on DABS.

1. Automated Traffic Advisory and Resolution Service (ATARS)

2. ATC Automation:

   - Altitude clearance confirmation
   - Take off clearance confirmation
   - Other clearance confirmations
   - MSAW advisories to pilots
   - Advanced metering and spacing
   - Automated en route air traffic control

3. Weather

   - Severe weather advisories
   - Surface observations, terminal forecasts, etc., (upon pilot request)
   - High resolution (1 nmi x 1 nmi) digitized weather radar data (upon pilot request)

4. Enhanced Terminal Information Service

   - Routine terminal information (as in current automated terminal information service)
   - Updates and alerts on changes in runway visual range, ceiling, visibility, etc.

5. Downlink of Aircraft Air Data for Wind Profile Generation

6. Uplink of Aircraft Ground Track Data for Redundant Navigation

## Environment

The analysis considers a high density air traffic model of the Los Angeles basin in the 1995 time frame. The air traffic model used contains 1105 aircraft within an area approximately 60 nmi in radius, and provides complete position and velocity information on each aircraft at an instant of time. The model is based on the latest FAA air traffic projections for the Los Angeles basin. The document shows that the traffic densities in the model used are very likely the highest that may be encountered by DABS during its lifetime. However, a sensitivity analysis is also conducted using two alternate traffic models, one 50% denser and one 50% sparser than the nominal traffic model. The recommendations presented in this study include the results from this sensitivity analysis.

Each aircraft in the traffic model is assigned DABS transponder equipage status in accordance with the projections used by the FAA in August 1979 in a draft DABS deployment plan. These projections result in about 80% of all aircraft being DABS transponder equipped. Very liberal assumptions regarding aircraft equipage with appropriate avionics for different services are made. Eight DABS sensors are assumed to serve this traffic. These include six sensors located at sites in the Los Angeles basin which currently have Automated Radar Traffic Control System (ARTS) facilities. Two more DABS sites are assumed for the purpose of providing effective coverage in the basin. Realistic maps of sensor responsibility are drawn for each sensor and include the provision for instantaneous backup in case of the failure of any one of the eight sensors.

## Analysis

An exact computer analysis is conducted for the eight-sensor configuration which provides the services outlined earlier in this traffic environment. Provisional data link formats defined by the DABS data link program have been used wherever available. ATARS data link formats in 1979 included a concept of the coordination of ATARS with the Beacon Collision Avoidance System (BCAS), called the Conflict Indicator Register (CIR). The computer analyses conducted for this study utilized the CIR concept. This concept has since been revised and is now replaced by another called the Resolution Advisory Register (RAR). The impact of the RAR has been assessed in all significant areas of data link utilization. The final recommendations regarding the required DABS data link capacity reflect the use of the RAR formats. The analysis includes reinterrogations due to link fades.

## Results

ATARS is found to be the most significant user of the DABS data link. Within ATARS, the proximity advisories account for the largest contribution in data link load. ATC services account for only about 5% of the total data link usage.

To be able to deliver all services assumed in this study without scan-to-scan delay, a DABS sensor must be capable of scheduling up to eight Comm-A transactions in one beam dwell of the radar to some of the aircraft. (Comm-A transactions are the basic tactical DABS data link transactions, capable of transmitting 56 data bits in a single message. A beam dwell is the time period required for the radar beam to pass over an aircraft.) Even if only the flight critical messages such as ATARS resolution or threat advisories and ATC messages should be required to be guaranteed delivery every scan, a DABS sensor must be capable of scheduling up to five Comm-A transactions during a single beam dwell to some of the aircraft.

A sensor in the future Los Angeles basin should be able to serve about 400 targets. These targets are not distributed uniformly over azimuth or range. Considerable azimuthal bunching is encountered. Recommended sensor performance is specified in terms of these expected peaks.

## Recommended DABS Data Link Capacity

In order to provide the services assumed in this study in the worst traffic environment that DABS may be expected to encounter, a DABS sensor should be capable of providing the data link performance summarized in Table I. DABS sensors of three capacities are recommended: 250 targets, 400 targets and 700 targets. The specifications in Table I apply to each of these. These specifications imply the ability to <u>schedule</u> such messages and include the expected loss of some messages due to link fades and interference.

The requirements in Table I are consistent with the upper limits of DABS message volumes established by the U.S. National Aviation Standard for DABS. These requirements are physically realizable by DABS within the constraints imposed by radio propagation delays and the properties of the current DABS message scheduling algorithm. (This study has not considered computer specific limitations such as computing speeds or software efficiency.)

TABLE I

RECOMMENDED DABS DATA LINK CAPACITY REQUIREMENTS(1)

| a | b | c | | | d | | | | e | f |
|---|---|---|---|---|---|---|---|---|---|---|
| Type of Peaking | Number of Targets (DABS & ATCRBS) | Number of Aircraft Receiving N Comm-As(2) Where N = | | | Number of Aircraft Transmitting N Long Replies3 Where N = | | | | Number of Aircraft Receiving 16 Segment Uplink ELMs(4) | Number of Aircraft Transmitting 16 Segment Downlink ELMs |
| | | 1 | 4 | 8 | 1 | 2 | 3 | 4 | | |
| 2.4° Beam Dwell | 15 | 4 | 5 | 3 | 3 | 2 | 1 | 1 | 1 | 0 |
| 11.25° Sector | 50 | 18 | 20 | 6 | 8 | 4 | 2 | 2 | 8 | 3 |
| 90° Quadrant | 250 | 90 | 85 | 25 | 32 | 16 | 8 | 8 | 40 | 15 |

NOTES:

(1) These specifications apply to DABS sensors of any one of three capacities (250, 400 or 700 targets).

(2) Comm-As are the standard 112 bit tactical uplink messages, capable of transferring 56 data bits each.

(3) These long (112 bit) replies are DABS replies to interrogations already being scheduled to that aircraft as indicated in column c.

(4) ELMs are extended length messages of up to 16 "segments" capable of transferring a total of up to 1,280 data bits. Uplink ELM numbers are dependent upon DABS National Standard maximum uplink message rate limits.

(5) Only DABS aircraft receive the data link messages summarized in this table. Each ATCRBS aircraft receives four ATCRBS surveillance interrogations each scan.

## Growth Capability

The specifications recommended in this document reflect the ability of DABS sensors to service the densest traffic environment projected to be encountered in future. However, it does not mean that the DABS <u>system</u> will become saturated when these traffic densities are reached. Each DABS sensor is analogous to a communication channel. An increase in demand for data link services due to an increase in traffic levels can be met by the deployment of additional sensors. Before additional sensors are so deployed, however, studies should be conducted to guarantee that the deployment of new sensors would maintain the airspace free of unacceptable radio frequency interference.

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(Concluded)

## 1. INTRODUCTION

The Federal Aviation Administration (FAA) plans to deploy the Discrete Address Beacon System (DABS) as a key feature of its upgraded third generation Air Traffic Control (ATC) System. DABS provides significant improvement over the current Air Traffic Control Radar Beacon System (ATCRBS) in its surveillance function. In addition, it provides an integral data link capable of conducting rapid transfer of data between the sensor and DABS equipped aircraft. This study establishes the performance requirements on the DABS data link to be able to provide the various services that may reasonably be expected to be delivered by DABS during its life time.

Interim results from this study have previously been documented in Reference 1. It was found at that point that while the interim analysis was useful for establishing the worst case Radio Frequency (RF) environment that DABS would present to other systems, it was not suitable for establishing design capacity requirements for the DABS data link. It was therefore recommended in Reference 1 to conduct further refinements. The refinements deal with two major areas: incorporation of the Automated Traffic Advisory and Resolution Service (ATARS) algorithms and formats which were undergoing change during the interim analysis and the revision of the traffic model used for exercising the worst case DABS deployment. The results of these refinements are reported in this document.

The ATARS algorithms used in this study employ a concept called the Conflict Indicator Register (CIR) for effective coordination between ATARS and the Beacon Collision Avoidance System (BCAS). The CIR concept has also since been revised into another one called the Resolution Advisory Register (RAR) (Reference 2). The RAR is more modest in the demands it places on the datalink than the CIR. This document includes a discussion of the impact of the RAR on the analysis conducted in this study. The performance requirements suggested in this document include the expected impact of the RAR.

The set of services forecast to become available by the year 1995 and used to establish the requirements in this document have been outlined in detail in the interim report (Reference 1). Reference 1 is therefore treated as a companion document to this paper. Those aspects uniquely incorporated since the interim analysis have been thoroughly discussed here. Others, already described in Reference 1 (mainly the material of chapters 2 and 3) are summarized, with an appropriate reference to the interim report.

This document is organized as follows: Chapter 2 provides a brief overview of the DABS data link function; Chapter 3 summarizes the services projected to be supported by DABS by the year 1995; Chapter 4 presents the projected worst case air traffic environment that DABS may encounter in the 1995 time frame; Chapter 5 provides the resultant data link loading; Chapter 6 discusses the sensitivity of the results to the model used; results presented in Chapter 5 and Chapter 6 form the basis of the recommended DABS data link capacity specifications presented in Chapter 7; and Chapter 8 presents the growth potential of DABS. It describes the capacity left over after providing all the services identified in this study and discusses methods of responding to further growth in demand.

Appendix A describes the revised Los Angeles Basin 1995 model (LAX-1100) used in this study. Appendix B describes the scheme for assigning avionics equipage to aircraft. Appendix C summarizes DABS theoretical channel capacity in terms of transactions per target per scan and also shows examples of some peak schedules as per the peak specifications recommended in this study. Appendix D includes, for reference and comparison, the various existing specifications for DABS engineering models and DABS radio signals.

## 2. THE DABS DATA LINK

DABS signals consist of uplink data messages sent from the ground sensor to the aircraft and downlink messages from the aircraft to be received by the sensor. Both uplink and downlink messages can be either "standard" or "extended length". Standard messages are fixed in length and each message requires a reply. (Every downlink reply is an acknowledgement of message acceptance by the transponder.) A standard uplink message is referred to as a "Comm-A" transaction while a standard downlink message is called a "Comm-B" transaction. Data link services which require urgent delivery and which are short in length (about 50 bits) utilize the standard formats. Extended length messages (ELMs) are used for applications which require the transfer of a large amount of text. Basically an ELM consists of a variable number of fixed length messages linked together and only requiring one reply for the entire message. The uplink ELM is a collection of "Comm-C" interrogations up to a maximum of 16 "Comm-C" segments. The downlink ELM makes use of "Comm-D" segments in a similar way. Table 2-1 summarizes the capabilities of these DABS message types.

The DABS system employs a priority system for delivery of these messages as follows.

Priority level 1: Surveillance messages and priority Comm-A and Comm-B messages

Priority Level 2: Normal Comm-A and Comm-B messages or the final Comm-C/Comm-D messages of an ELM (NOTE: Developments are currently underway to include priority uplink ELM segments at this priority level.)

Priority Level 3: Uplink ELM segments

Priority Level 4: Downlink ELM segments

Messages with priority 1 are given priority over messages with priority 2, and so on. Priority assignments are made by the user (e.g., ATARS, ATC, etc.). The priority scheme guarantees that high priority tactical Comm-A and Comm-B messages are delivered before all other messages. A detailed discussion of data link formats and protocols is provided in References 1 and 3.

TABLE 2-1

DABS MESSAGE TYPES

| Type | Message Length (Bits) | Includes Surveil- lance | Number of Data Bits | Transmission Time (Microseconds) |
|---|---|---|---|---|
| Uplink | | | | |
| Surveillance Interrogation | 56 | Yes | 0* | 19.75 |
| Comm-A | 112 | Yes | 56 | 33.75 |
| Comm-C | 112 | No | 80 | 33.75 |
| Downlink | | | | |
| Surveillance Reply | 56 | Yes | 6 | 64 |
| Comm-B | 112 | Yes | 56 | 120 |
| Comm-D | 112 | No | 80 | 120 |

*Some bits are also available in surveillance interrogation for control of onboard ATARS & BCAS

## 3. PROJECTED DATA LINK SERVICES

The DABS data link will be the vehicle for providing many services which will contribute to the safety of aircraft, increase capacity of airports, increase controller productivity and which will facilitate introduction of procedures for maximum energy conservation. One of the most notable amongst these future services is the provision of automatic collision avoidance advisories to aircraft. There are also many other services, such as the automatic transfer of ATC messages, that the data link will facilitate. Certain desirable enhancements in the current ATC system through increased automation would not, in fact, be realizable without the data link. This chapter identifies services that may reasonably be considered to become available by the end of the first ten years of DABS deployment. Table 3-1 lists these services and the enhancements resulting from each. These services have been identified in this study by the author on the basis of known FAA commitments and development programs. This list is not an official FAA list. The set of services being considered by the FAA for implementation in the early years of DABS (Reference 4) does, however, form a subset of the list proposed here. A detailed discussion of all these services can be found in Reference 1. This chapter only provides a detailed description of ATARS, whose algorithms and formats have undergone a change since the interim study (Reference 1). A summary of message transactions required by each service is included at the end of this chapter. Avionics equipage requirements for each service are identified in a later chapter.

### 3.1 Automatic Traffic Advisory and Resolution Service (ATARS)

ATARS is a software system that provides a traffic advisory service in routine as well as potential collision situations. Whenever two aircraft come into a potential collision situation, ATARS provides appropriate warnings directly to the DABS/ATARS equipped aircraft involved in the encounter and suggests a course of action. The service is not restricted to controlled aircraft; it is available to any DABS/ATARS equipped aircraft that is within coverage of the associated DABS sensor. The service also automatically provides aircraft with advisories on proximate traffic, identifying as "threats" those aircraft on a potential collision course. The system is described in full in Reference 5.

TABLE 3-1

SERVICES EXPECTED WITHIN TEN YEARS AFTER DABS DEPLOYMENT
AND THE RESULTING SYSTEM ENHANCEMENTS

| Service | Enhancement | | | |
|---|---|---|---|---|
| | Safety | Capacity | Productivity | Energy Conservation |
| <u>Automated Separation Assurance</u> | | | | |
| o Automatic Traffic Advisory and Resolution Service (ATARS) | X | --- | --- | --- |
| o Provide Coordination Between ATARS and BCAS | X | --- | --- | --- |
| <u>Automation of ATC Services</u> | | | | |
| o Automated Minimum Safe Altitude Warning to Pilots | X | --- | X | --- |
| o Confirmation of Clearances for Routing, Departure, Altitude Assignment, Holding and Approach | X | --- | X | --- |
| o Voice Frequency Assignments For ATC Handoff Automation | --- | --- | X | --- |
| o Advanced Metering and Spacing | --- | X | X | X |
| o Automated Clearances | X | X | X | X |
| o Flight Plan Revisions | --- | --- | X | --- |

TABLE 3-1
(CONCLUDED)

| Service | Enhancement | | | |
|---|---|---|---|---|
| | Safety | Capacity | Productivity | Energy Conservation |
| <u>Other Services</u> | | | | |
| o Weather | | | | |
| - Severe Weather Advisories | X | --- | --- | --- |
| - Weather Information For Pilot-Requested Site | --- | --- | X | --- |
| - Digitized Weather Map | X | X | X | X |
| o Enhanced Terminal Information Service | | | | |
| - Routine Terminal Information Including Runway In Use And Local Weather | --- | --- | X | --- |
| - Environmental Updates And Alerts, Wind Shear, Changes in Runway Visual Range, Changes in Ceiling, Changes in Visibility, Changes in Runway, Change In Altimeter Setting, Sudden Temperature Or Pressure Drops, Etc.) | X | --- | X | --- |
| o Wind Profile Generation Through Downlinked Air-Data | --- | X | --- | X |
| o Redundant Navigation Through Uplinked Ground-Data | X | --- | X | --- |

Messages generated by ATARS may be grouped under four types:

1. Proximity advisories
2. Threat advisories
3. Resolution advisories
4. Overhead messages

Data Link implications of these are discussed in turn.

### 3.1.1 Proximity Advisories

Proximity advisories are used to inform a pilot of nearby proximate aircraft. This proximity, described in detail in Reference 5, is basically defined by a plus or minus 2000 ft altitude difference and a range corresponding to 30 seconds at the combined speed of the two aircraft involved. The message contains sufficient information to indicate the bearing, relative altitude and heading of the other aircraft. Two such proximity advisories can be packed in one Comm-A message to an aircraft. (See Reference 6.) This Comm-A message is assigned "normal" priority in the DABS schedule.

### 3.1.2 Threat Advisories

A threat advisory message is issued to warn pilots of a potential collision situation. This message is given approximately 15 seconds or more in advance of a resolution advisory to give the pilots involved time to resolve the conflict on their own by locating each other visually using the relative bearing, altitude, and heading data from the threat advisory message. The threat advisory message requires one Comm-A for transmission of the data relating to a single threat aircraft and is assigned "high" priority in scheduling.

ATARS provides for advisories to an individual subject aircraft on a maximum of eight separate intruders. If the logic should detect more than eight intruders (proximities and threats) only eight are provided to DABS for transmission. Traffic advisories are ranked by urgency. Threats are always ranked higher than proximities. Further, intruders within each category (i.e., proximities or threats) are also ranked, assuring an overall ordering of these traffic advisories by their urgency.

### 3.1.3 Resolution Advisories

Resolution advisories are issued to aircraft whenever they are detected to be sufficiently close in range and closing towards each other at a high enough rate to be in imminent danger of collision. The actual effective lead time provided to an aircraft for such collision avoidance is a function of many things including its control status, intruder equipage, the speed of the two aircraft, and traffic areas. The algorithms of Reference 5 have been used in the current analysis to determine when to issue these advisories.

Formatting of resolution advisories for uplinking has undergone considerable change during the development of the DABS/ATARS concept. The formats used in this study are governed by the so-called "Conflict Indicator Register" (CIR) concept, described in Reference 7 and Reference 8. The CIR is a resolution advisory storage device on board each aircraft equipped to receive ATARS service. The CIR information and protocols are designed to provide proper coordination between ATARS and the Beacon Collision Avoidance System (BCAS). They also provide for a coordination of conflict resolution information between adjacent ATARS sites in case of an absence or failure of ground communication between them. Each ATARS site performs ATARS computations for all aircraft within a specified geographical area which represents the area of responsibility of that ATARS. These areas of responsibility overlap in the vicinity of their boundaries to form seam areas in which two or three ATARS functions may have responsibility. The generation of incompatible resolution advisories to a pair of aircraft by two different ATARS functions is prevented by assigning a priority ordering to sites which provide service in the seam between sites. The site which sees both the aircraft and has the highest priority is allowed to resolve the conflict.

The coordination concept involves the uplinking of conflict resolution and other information on each intruder into the CIR from each responsible site, and the downlinking of the entire CIR contents by each responsible site. These messages are all assigned "high" priority. Information on DABS intruders requires one row per DABS intruder in the CIR and information on ATCRBS intruders requires two rows per ATCRBS intruder. Uplinking and downlinking of CIR rows is accomplished through Comm-A and Comm-B messages, requiring one message per row. When all necessary transactions have taken place, a closeout transaction is necessary. This final closeout requires a few bits of information and can be done in a surveillance transaction.

ATARS also provides an alert to pilots when a violation of restricted airspace or collision with terrain or obstacles is imminent. However, these messages are not modelled in this study.

It should be noted that, since the completion of this analysis, these formats have been further changed. A new concept called the Resolution Advisory Register (RAR) is now used for ATARS/BCAS coordination instead of the CIR (Reference 2). The quantitative analysis conducted in this study utilizes the CIR concept. The RAR places more modest demands on the data link. The impact of the RAR has been identified in this document at appropriate places. The DABS capacity requirements established later in the document incorporate the expected use of the RAR concept.

### 3.1.4 Overhead Messages

ATARS issues certain overhead messages, called "start/end messages" and "own messages". These are discussed in this section. A detailed discussion of their formats can be found in References 6 and 7.

ATARS issues a 24-bit message at the start and the end of each encounter (proximity or threat). Assuming an average duration of 18 scans for an encounter, such a message would be required twice in 18 scans.

A 24-bit "own-message" is issued once a minute, or at the beginning or the end of a turn or upon entering a seam area. Table 3-2 summarizes these events and the resulting probabilities of issuing an own-message on an individual scan of the radar. An average time of seven minutes between seam boundaries is assumed for the multisite DABS sensor coverage map discussed in greater detail in Chapter 4. An average duration of six scans is assumed for turns.

When there are an odd number of proximities, these overhead messages can fit into a Comm-A meant for the odd proximity. However, when the number of proximities are even, the overhead messages cause the issuance of an extra Comm-A. These considerations are incorporated in the analysis.

## 3.2 Formats for Services

Table 3-3 identifies the DABS formats required for delivering the services listed in Table 3-1 and provides the frequencies with which each service is expected to be delivered to those aircraft eligible for it. ATARS message rate requirements can only be determined from exercising the ATARS algorithms on given traffic conditions. This is described in Chapter 5. Other services require Comm-A, uplink ELM or Comm-B transmissions as indicated.

TABLE 3-2

PROBABILITY OF ATARS OVERHEAD MESSAGES

| Message Type | Triggering Conditions | Assumed Duration Of Event | Probability Of Message |
|---|---|---|---|
| Start/End Of Encounter | Proximity Or Threat | 72 Seconds | $2 \times \frac{4}{72} = 0.11$ Per Encounter |
| Own Message | Seam Crossing | 7 Minutes | $\frac{4}{420} = 0.01$ |
| | Once A Minute | 1 Minute | $\frac{4}{60} = 0.07$ |
| | Start Or End Of Turn | 6 Scans | $\frac{2}{6} * p(Turn)$ |

TABLE 3-3

SUMMARY OF SERVICES AND THEIR FORMATS

| Services | | Type of Data Link Messages Required | Frequency of Service (to eligible aircraft)(1) |
|---|---|---|---|
| ATARS | | Comm-As: 2 Proximities per Comm-A; 1 Threat in 1 Comm-A; Overhead Messages<br>Comm-As & Comm-Bs for CIR | Frequency is Function of ATARS Logic & Aircraft Distribution |
| ATC | Urgent | 1 Comm-A per Message | Probability 0.3 of a Message on Any Given Scan |
| | Record | Uplink ELM of 2 Segments | Once per 1 Hour Flight |
| ETIS & Weather | Urgent ETIS | 1 Comm-A per Message | Probability 0.09 of a Message on Any given Scan |
| | Routine ETIS & Pilot Requested Weather By Site | 6 Uplink ELMs (an Average of 10 Segments each) +1 Comm-B per Request(2) | Once per 1 Hour Flight |
| | Digitized Weather Radar | 1 Uplink ELM of 16 Segments +1 Comm-B per Request(2) | Once Every 15 Minutes |
| Redundant DABS-Navigation Through Uplink of Ground Data | | 1 Comm-A | Once Every 2 Scans |
| Wind Profile Generation Through Downlink of Air Data | | 1 Comm-B | Once Every 6 Scans |

(1) From Reference 1.
(2) These data are transmitted upon pilot request. A pilot request is received via a pilot initiated Comm-B.

The actual load on a DABS sensor depends upon the target populations utilizing each type of service and their spatial distributions. These are discussed and analyzed in the next two chapters.

# 4. PROJECTED USER ENVIRONMENT

The data link utilization levels for any given sensor are determined by the number of aircraft utilizing each type of service which, in turn, is determined by avionics equipage. In addition, ATARS messages are also determined by the characteristics of surrounding traffic. This Chapter identifies expected characteristics of the 1995 user environment in terms of its DABS transponder and other avionics equipage. It then presents the expected air traffic in the Los Angeles Basin in 1995 as the worst environment that DABS may have to encounter. The model presented here is a more realistic revision of the traffic model of Reference 9, used in earlier data link studies (Reference 1). Finally, the sensor deployment scheme utilized in this analysis is described.

## 4.1 Avionics Equipage

Reference 10 presents expected DABS equipage in 1994 in terms of four classes of users. These are summarized in Table 4-1. Air carriers and high performance general aviation (GA) aircraft are expected to be equipped with high cost avionics disigned to meet ARINC (Aeronautical Radio, Inc.) specifications. Medium and low performance GA aircraft are expected to be equipped with less sophisticated low-cost avionics. The table also describes the user composition of each avionics class.

Table 4-2 presents national fleet forcasts and DABS transponder equipage for 1994. It is based on information in Reference 10. All classes of users except the class of low-performance general aviation aircraft are expected to be 100% equipped with DABS transponders. 71.9% of the general aviation aircraft are expected to be equipped with DABS transponders in 1994.

Table 4-3 summarizes the services presented in Chapter 3, their target populations, their avionics requirements and their expected equipage levels. Of course, all aircraft receiving data link service must be at least DABS equipped. The "target population" column identifies the particular sub-population of all DABS equipped aircraft that are eligible to receive each service. The population actually receiving the service is that part of the DABS equipped target population that becomes equipped with the required display avionics. These avionics requirements are identified in Table 4-3. Also included in Table 4-3 are the percentages of the "target populations" that may be expected to be so equipped within ten years of the deployment of DABS. All DABS equipped aircraft are assumed to possess the capability to accept Uplink ELMs. This is a

TABLE 4-1

USER AVIONICS CLASSIFICATION

| Class | Population | Description |
|---|---|---|
| A | Air Carriers | Redundant High Cost Avionics |
| B | High Performance GA<br>- All turbine GA<br>- 10% of Reciprocating Multi-Engine GA | High Cost Avionics (non-redundant) |
| C | Medium Performance GA<br>- 90% of Reciprocating Multi-Engine GA | Low Cost Avionics |
| D | Low Performance GA<br>- Single Engine GA | Low Cost Avionics (those who do equip. Not all do) |

NOTE: GA = General Aviation

TABLE 4-2

NATIONAL FLEET AND DABS EQUIPAGE FORECASTS FOR 1994

| Class | Fleet Type | Total | New* | % of Fleet Equipped With DABS |
|---|---|---|---|---|
| A | Air Carrier | 3,463 | 930 | 100% |
| B | High Performance General Aviation | 19,200 | 9,800 | 100% |
| C | Medium Performance General Aviation | 41,000 | 17,500 | 100% |
| D | Low Performance General Aviation | 250,300 | 93,800 | 80% of New<br>67% of Old<br>Net: 71.87%<br>Are Equipped |
| | Total | 313,963 | | 77.5% |

* New aircraft are those commissioned after 1983.
Data extracted from Reference 10.

TABLE 4-3

DATA LINK SERVICES TARGET POPULATIONS

| Service | Target Population(2) | Minimum Required Avionics | | Part of Target Population Assumed Equipped With Required Avionics Within Ten Years of DABS Deployment |
|---|---|---|---|---|
| | | Display Requirements | Transponder Capability | |
| ATARS | All | ATARS Display | Comm-A/Comm-B | 100% |
| ATC Services | IFR and Controlled VFR | Alphanumeric | Comm-A/Comm-B | 100% |
| Digitized Weather | All | Alphanumeric(1) or Graphical | Comm-B & Uplink ELM | 100% |
| ETIS & Routine Weather on Pilot Request | All | Alphanumeric | Comm-B & Uplink ELM | 100% |
| Routine ATC (Flight Plan Revision) | IFR | Alphanumeric | Comm-B & Uplink ELM | 100% |
| Downlink of Airborne Data | All | Airborne Sensors & Translators To Transponder | Comm-B | Avionics Categories A, B, and C |
| Uplink of Ground Data | All | Alphanumeric | Comm-A | 100% |

(1) Anywhere from low-cost printer to sophisticated electronic display
(2) Service is only available to DABS equipped aircraft. DABS equipage is determined by Table 4-2.

conservative estimate and does not reflect the various functional configurations available for DABS transponders. All services are expected to be available within five years after DABS deployment. Each target population is assumed to become fully and appropriately equipped within five years after a service is offered. This yields a 100% equipage within ten years of DABS deployment. The one exception to this is downlinking of air data. Downlinking of airborne data requires special airborne sensors and the ability to code that data into a form acceptable to the transponder. Therefore, it is assumed that no low-performance (that is, single engine) general aviation aircraft would obtain such capability. Our equipage assumptions are thus quite conservative, leading to liberal higher bounds for percentages of aircraft assumed to be equipped.

## 4.2 The Traffic Model

The 1995 Los Angeles basin was selected to represent the worst possible traffic situation that a DABS sensor may ever experience. For exact computations of message and target loads on DABS sensors, it is necessary to employ an air traffic model providing realistic position and velocity information on each target. Appendix A describes the traffic model used in this study. This model, called LAX-1100, contains 1105 aircraft in a region approximately 60 nmi in radius centered at the Los Angeles International (LAX) VORTAC. This model is derived from a model described in Reference 9 which contains 1840 aircraft. This latter model was built in 1972 on the basis of FAA forcasts available then. LAX-1100 simply revises it on the basis of the most current FAA forecasts. A complete description of its derivation is provided in Appendix A.

LAX-1100 represents the best estimate of the densest air traffic situation that DABS would be required to handle. All the major analyses presented in this study are based on this model. Predicting future traffic levels, however, is necessarily fraught with uncertainties. Therefore, two more traffic models, one about 50% denser and one about 50% sparser than the nominal (LAX-1100) model have also been generated for use in a sensitivity analysis. These models and the corresponding sensitivity analysis are presented in chapter 6. A discussion of the validity of using the LAX-1100 model to represent the heaviest expected loading during the lifetime of DABS is also deferred to Chapter 6.

The LAX-1100 model provides the following information on each aircraft: position, velocity, user type (air carrier, general aviation or military), flight plan status (Instrument Flight

Rules (IFR) or Visual Flight Rules (VFR)), flight type (local or itinerant) and aircraft category (single engine, multi-engine, turbine, etc.). It was assumed that DABS and avionics equipage in the Los Angeles basin would be proportional to the national fleet numbers presented earlier in Table 4-2.

LAX-1100 subtotals, however, do not necessarily match these proportions. Therefore a mapping is made from the proportions of Table 4-2 into the LAX-1100 model. Counts for IFR and controlled VFR traffic are required for estimating ATC service requirements. The DABS transition plan does not make estimates of traffic counts for controlled aircraft nor does the LAX-1100 model contain categories to enable such estimates. These estimates were obtained from Reference 11, and mapped into the LAX-1100 model. A detailed discussion of these computations is presented in Appendix B.

## 4.3 Sensor Deployment

The Los Angeles basin would undoubtedly be served by a network of several sensors. It was assumed that eight sensors would be deployed in the basin. The following factors were considered in determining their locations:

1. Locations of Existing ARTS sites
2. Back up capability in case of failed sensors.
3. Best floor of coverage
4. Demand

According to the DABS Transition Plan (Reference 10), DABS sensors of the first acquisition would be located at existing ARTS-III sites and some ARTS-II sites. The Los Angeles basin already has five ARTS-III sites (Burbank, Long Beach, Los Angeles International, Ontario and Santa Ana). Figure 4-1 shows the topography of the Los Angeles basin and its airports. All five sites are seen to be located south of the major mountain range in the basin. The LAX-1100 model, however, also contains considerable traffic north of the mountains. Most of this traffic would not effectively be covered by these five sites. At least one DABS site should therefore be located in the northern section of the basin. Palmdale is the logical choice for this since it already has an ARTS-II system. In this study, effective coverage is desired with any one of the eight sensors failing. Another site is therefore assumed to be deployed in the northern region of the basin, at George AFB, currently a towered airport. The eighth sensor is assumed to be located at Norton AFB, since LAX-1100 shows considerable activity in that region. Table 4-4 lists the eight sensors used.

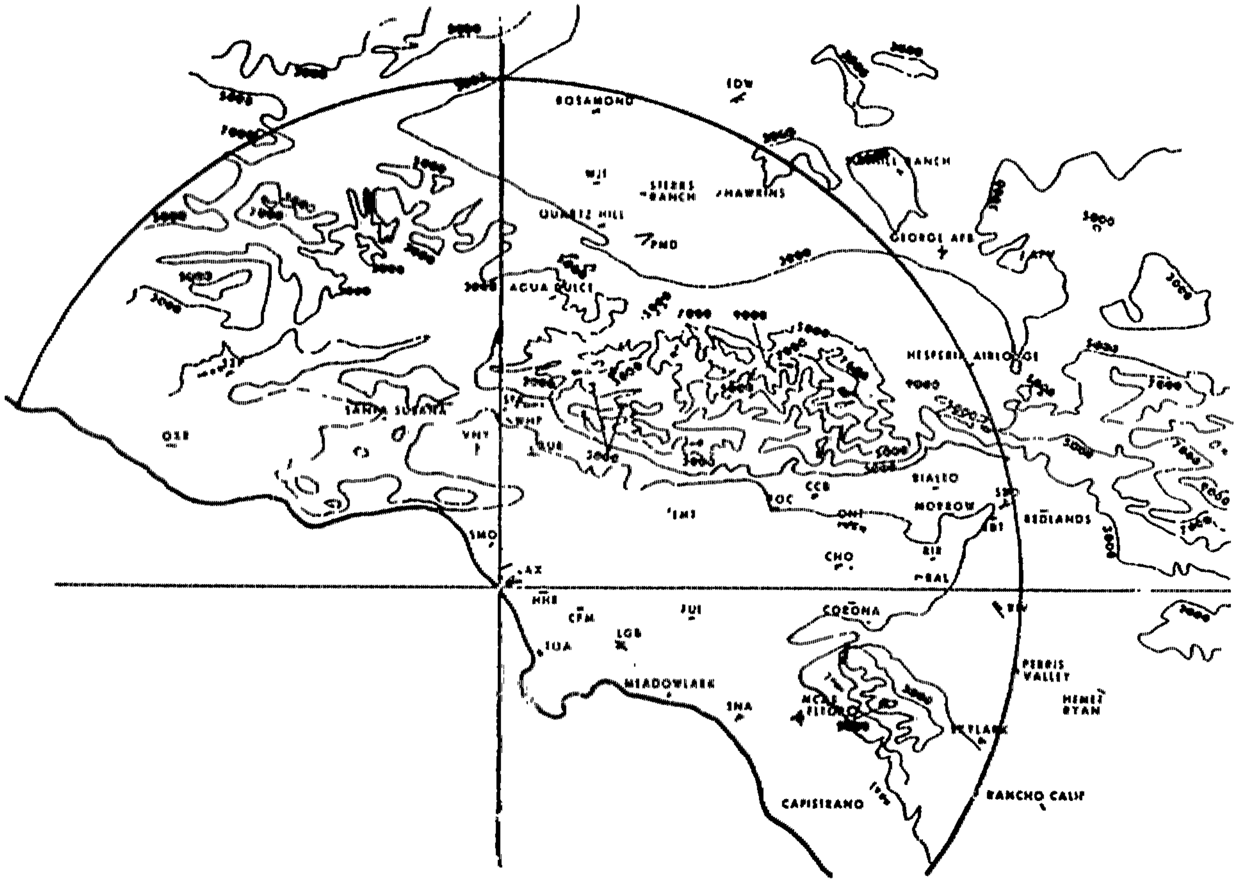



**FIGURE 4-1**
**TOPOGRAPHY OF THE LOS ANGELES BASIN AND AIRPORTS IN THE LAX-1100 TRAFFIC MODEL**

TABLE 4-4

LOCATIONS OF DABS SENSORS ASSUMED TO SERVE LAX-1100

| Number | Location | Abbreviation |
|---|---|---|
| 1 | Long Beach | LGB |
| 2 | Santa Ana | SNA |
| 3 | Ontario | ONT |
| 4 | Norton AFB | SBD |
| 5 | George AFB | VFV |
| 6 | Palmdale | PMD |
| 7 | Burbank | BUR |
| 8 | Los Angeles International | LAX |

Figure 4-2 shows the nominal responsibility map for the eight sensors. The area surrounding each sensor is designated here as the area of primary coverage responsibility for that sensor and that sensor is called the local or primary sensor for that area. The sensors are assumed to be interconnected by a ground communications network. All data link services to an aircraft are assumed to be provided by its local sensor. In the DABS concept (Reference 12) primary sensors for IFR aircraft may not always be the "local" sensors as assumed here. However, the ground communications network assumed in this analysis allows local sensors to always be used for the transaction of all data link messages. ATARS resolution advisories follow a somewhat more complex protocol. This protocol is described later in this section.

The boundaries of these areas of primary coverage responsibility are drawn so as to provide the best coverage of the airspace everywhere. In flat regions, these are obtained by the set of perpendicular bisectors of the lines connecting the sensors. Thus, the boundary between the jurisdiction of the sensors at SNA and ONT is the perpendicular bisector of the line joining SNA and ONT. This is so because in the absence of any obstruction, the lowest floor of coverage at a place is provided by the sensor nearest to it. In case of mountainous terrain however, unless the distance of the mountain range from the sensor is so large that the entire range is under the floor of coverage, the boundary should be drawn at the crest line of the mountain range. The southern boundaries for PMD and VFV exhibit this situation.

The CIR protocol for ATARS resolution advisories requires the establishment of seams at all boundaries shared by two sensors. Figure 4-3 shows the seam definition used in this study. Each sensor providing ATARS service is asigned one of four ATARS IDs, from 1 to 4. The seam is bounded by the nominal boundary and a line parallel to the nominal boundary 10 nmi from it, towards the site with the higher ATARS ID. (The seam definition in Reference 12 is slightly different. There, the seam area is centered on the nominal boundary.) For an aircraft outside the seam, only the primary sensor downlinks CIR rows. For an aircraft inside the seam boundaries, both sensors responsible for the seam need to downlink all CIR rows.

Figure 4-4 shows the seam boundary map for the eight sensor deployment. Thick lines show the nominal coverage map and thin lines show parallel seam boundaries. Numbers associated with sensors show their ATARS IDs.

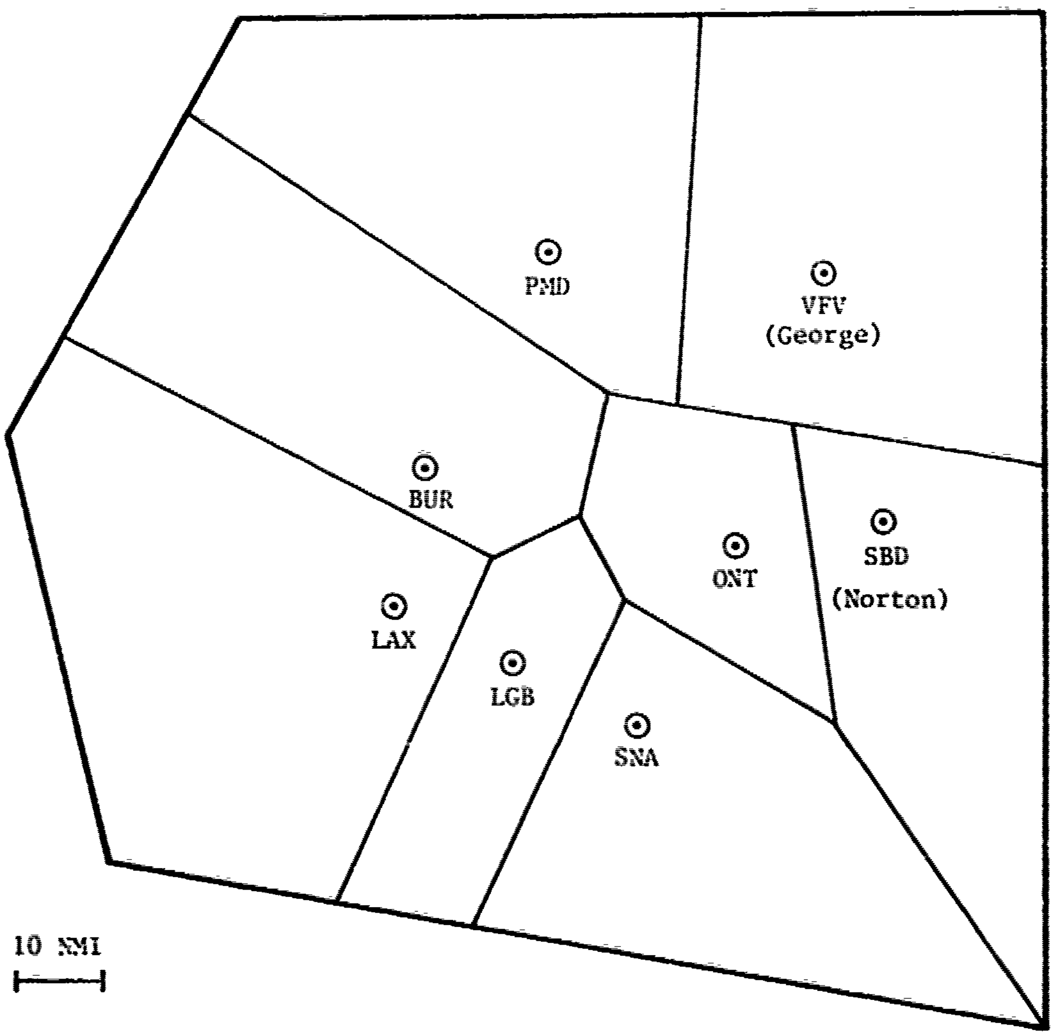



**FIGURE 4-2**
**NOMINAL COVERAGE MAP FOR DABS SENSORS IN THE LAX-1100 MODEL**

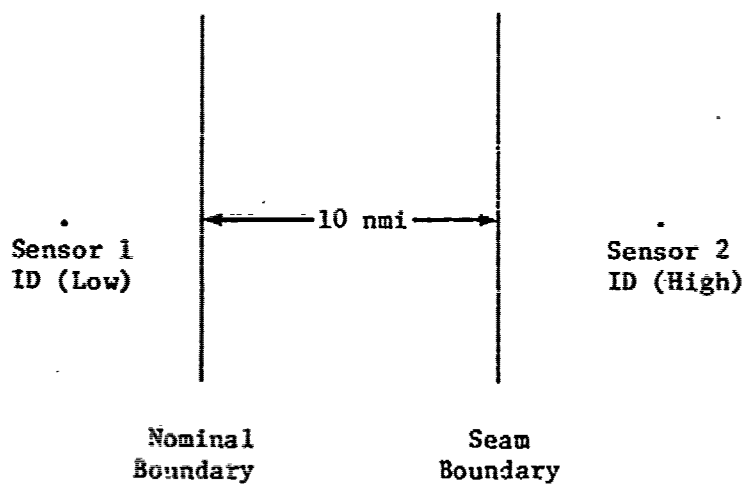



**FIGURE 4-3**
**MULTISITE ATARS SEAM DEFINITION**

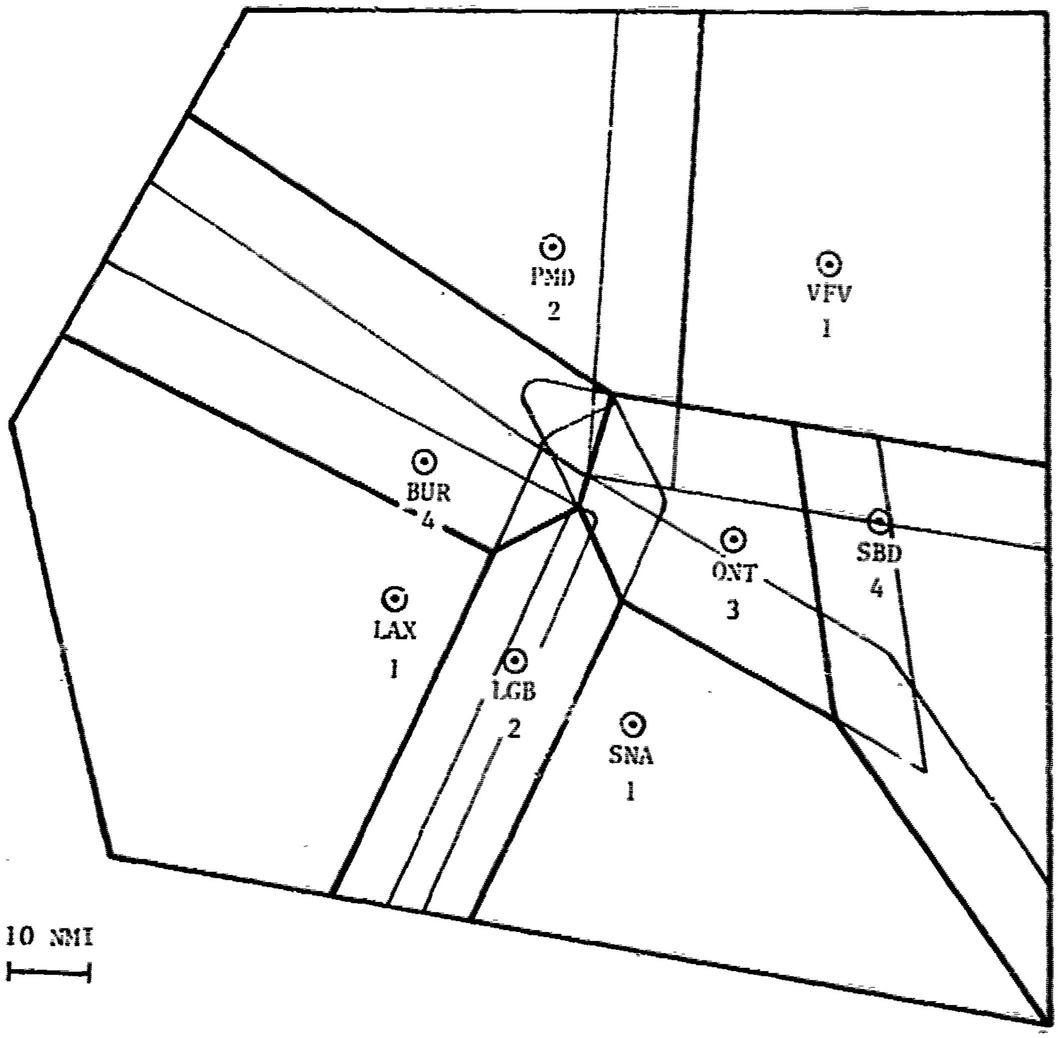



**FIGURE 4-4**
**MAP OF SEAM BOUNDARIES FOR MULTI SITE CONFLICT COORDINATION IN THE 1995 L.A. BASIN**

In case a sensor fails, adjacent sensors must reconfigure so that the area of primary coverage of the failed sensor is now serviced by other functioning sensors. A reconfiguration map for each case of a failed sensor was created for this study. As an example, Figure 4-5 shows the map of coverage when the sensor at Norton AFB fails. Its area of coverage is seen to have been divided up and assumed by two of its adjacent sensors, ONT and SNA. VFV is not assigned any of Norton's area because of terrain obstruction considerations. Of course, each failed sensor map also has its own associated ATARS seam map.

Since instantaneous back-up is desired in the event of a sensor failure, each sensor must maintain surveillance on all airspace that it may have to so service. This total area over which a sensor maintains surveillance is simply the union of the eight areas of primary coverage for that sensor corresponding to the cases of each of the other seven sensors failing and the case when no sensor has failed.

Finally, it should be noted that although sensor responsibility maps are drawn to reflect realistic methods of assigning coverage responsibility, floor of coverage effects regarding target visibility are not modeled in this study. Each aircraft within a sensor's coverage responsibility is assumed to be "visible" to that sensor, regardless of the aircraft's altitude. This is thus a conservative assumption in terms of target loads preserved to the sensor. In actuality, aircraft lying below the floor of coverage for a particular sensor will not be seen by that sensor.

In summary, the 1995 Los Angeles Basin is assumed to be served by a network of eight DABS sensors. Each sensor is required to provide surveillance and data link services over a part of the total airspace. Sensor jurisdiction maps are drawn so as to provide the best possible coverage everywhere. The system allows for an instantaneous back up in case of any one sensor failing. ATARS multisite protocols are incorporated and are reflected in seam areas of the jurisdiction maps.

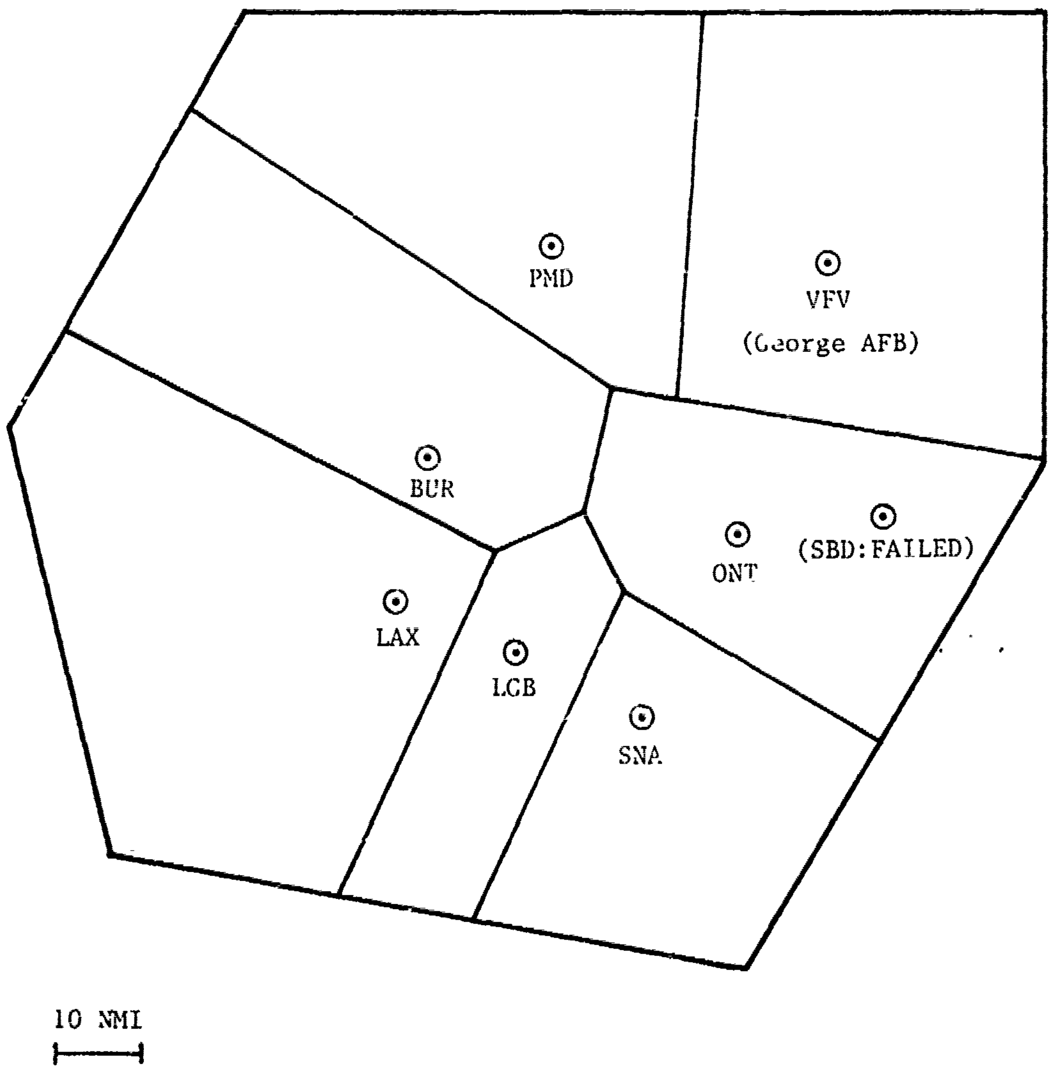



**FIGURE 4-5**
**COVERAGE MAP WHEN THE DABS SENSOR AT NORTON AFB FAILS**

# 5. DATA LINK LOADING

This chapter presents counts and histograms of DABS uplink and downlink messages in the 1995 Los Angeles basin for all its DABS sensors.

## 5.1 Methodology

Three computer programs, named "DUA", "MSGS" and "CIRBUN" incorporate all the data link loading considerations presented so far. Together, they accept an aircraft file and a sensor jurisdiction map as inputs and they output data link loading for any designated sensor. Figure 5-1 shows the flow of computation. Program DUA accepts the LAX-1100 data set and first labels each aircraft as DABS equipped or DABS unequipped. Appendix B shows that 32% of the single engine aircraft in LAX-1100 should be labeled unequipped. A random number generator is used to implement this labeling. Next, the program DUA exercises the ATARS algorithms of Reference 5 on the entire model. Most ATARS parameters are set to values indicated in Reference 5, except for the changes shown in Table 5-1. The look ahead parameters (TFPWI, TCMDH, and TCMDV, all with UUIND = 2) apply to encounters between two uncontrolled aircraft where one of them is unequipped and the speed of the equipped aircraft is less than 1.5 times the speed of the unequipped aircraft. The parameter values in Reference 5 for such encounters provide for more than 30 seconds extra time above and beyond that allowed for the case when both uncontrolled aircraft are equipped. These values are somewhat excessive and the later ATARS design (Reference 7) utilizes lower values for these parameters. These lower values, shown in Table 5-1, have been used in this study. The value of RDIST is reduced for the following reason. It can be seen from Figure 4-4 that each ATARS jurisdiction is wholly contained within 50 nmi of its sensor. ATARS parameters undergo an expansion past the range of 50 nmi. These expansions should therefore never be experienced in this deployment. However, in this analysis, ATARS messages are first computed in the program DUA assuming a single sensor at the origin. There are many aircraft in LAX-1100 at ranges greater than 50 nmi from the origin. For those aircraft, program DUA would expand the parameters, thus increasing the number of ATARS messages erroneously. Changing the value of the parameter RDIST to 100 nmi prevents this from happening since all aircraft in the LAX-1100 model lie within 100 nmi of the origin.

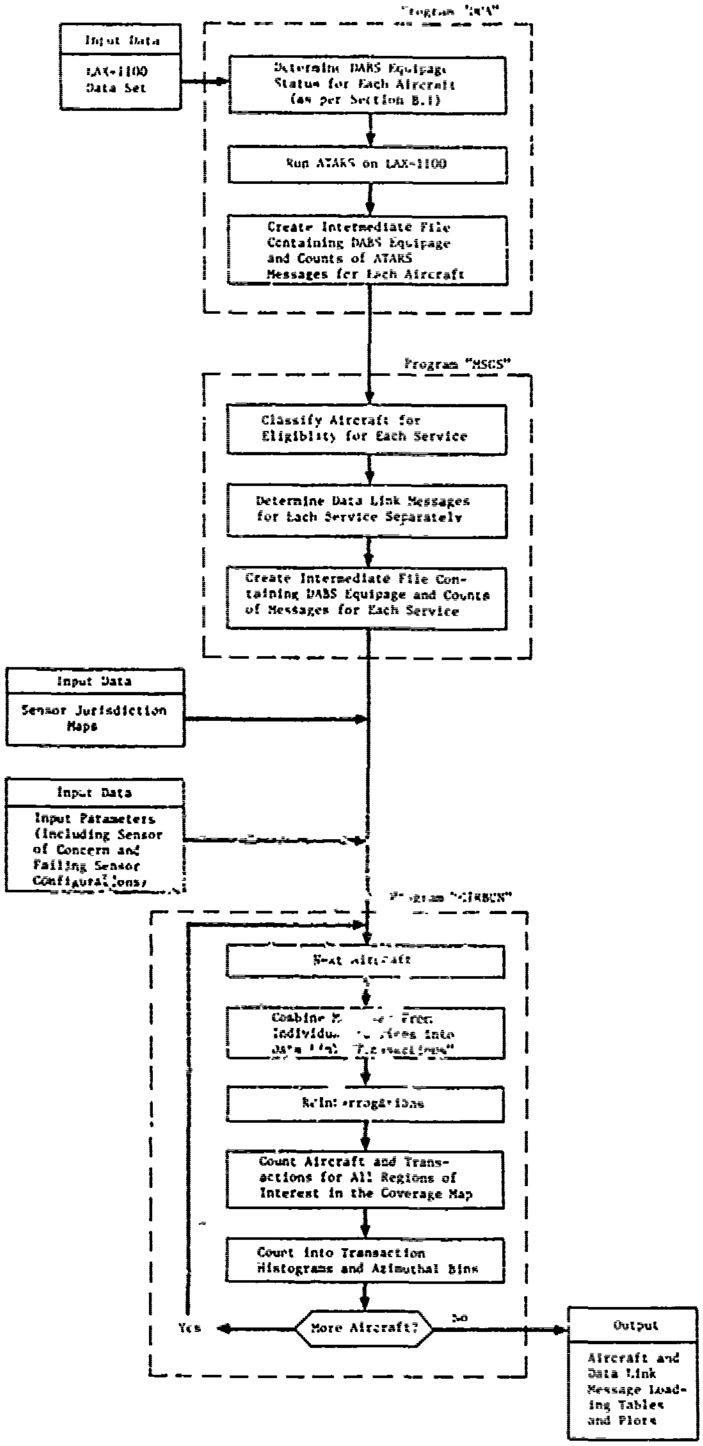



**FIGURE 5-1**
**DATA LINK LOADING: FLOW OF COMPUTATION**

TABLE 5-1

PARAMETER VALUE DEVIATIONS FROM NOMINAL ATARS[1]

| Parameter | Value in Reference 5 | Value Used in This Analysis |
|---|---|---|
| RDIST | 50 nmi | 100 nmi |
| TFPWI (UUIND = 2) | 75 sec | 53 sec[2] |
| TCMDH (UUIND = 2) | 64 sec | 40 sec[2] |
| TCMDV (UUIND = 2) | 64 sec | 40 sec[2] |

(1) Reference 5
(2) From Reference 7

The program DUA outputs a file which contains, for each aircraft, its DABS equipage status, a count of ATARS traffic advisories (threats and proximities) to be issued to it, and counts of DABS and ATCRBS aircraft producing resolution advisories to it.

Program MSGS accepts this intermediate file of all the aircraft in the basin and processes it on a per aircraft basis. It first determines the aircraft's "eligibility" for receiving each service. "Eligibility" simply indicates that the aircraft belongs to a subpopulation which may receive that particular service. Chapter 4 and Appendix B develop these eligibilities in terms of percentages of specific sub-populations. A random number generator is therefore used where appropriate to label each aircraft for service "eligibility". The program MSGS then determines the data link messages to be delivered to each aircraft depending upon the probabilities of receiving each service as summarized in Table 3-2. This also includes computing Comm-As for ATARS traffic advisories and Comm-As and Comm-Bs for the CIR. In this study, it is assumed that each responsible site (i.e., the primary site in the primary region and both adjacent sites in the seam areas) uplinks and downlinks all CIR rows each scan. In the actual algorithms, although the entire CIR is downlinked by each reponsible site, each site only uplinks those conflicts that it detects. The program MSGS also models the variation in the number of Comm-As and Comm-Bs due to the CIR during the lifetime of a conflict. Thus, on the first scan when a conflict is detected the sensor uplinks Comm-As but there are no Comm-Bs to downlink, since the CIR is empty. During the conflict, Comm-As are uplinked and Comm-Bs are downlinked. At the end of a conflict, the CIR is downlinked but there are no uplinks. Since LAX-1100 is a single scan model, it was assumed that each conflict had an average duration of eight scans and a probability of being in any particular phase of the conflict was assigned to each conflict in the model on that basis. Table 5-2 shows the probabilities for each particular sequence of message transactions for any given conflict for transferring CIR data.

Program MSGS outputs a file which lists each aircraft with its position information and lists the messages that each service requires. It continues to include ATARS advisory counts for future compilations. If there are no Comm-A or Comm-B messages from any services, a surveillance message is included for providing surveillance.

TABLE 5-2

DATA LINK MESSAGES FOR A TRANSFER OF CIR DATA

ND = Number of DABS Intruders
NA = Number of ATCRBS Intruders
Assumed Average Conflict Duration = 8 Scans

| Probability p | Sequence of Messages | |
|---|---|---|
| | Number | Type |
| p = 1/8 | (ND + 2NA) | Comm-A |
| p = 1/8 | 1<br>(ND + 2NA - 1)<br>1<br>1 | Comm-A(1)<br>Comm-A/Comm-B<br>Comm-B<br>Surv(2) |
| p = 5/8 | (ND + 2NA)<br>1 | Comm-A/Comm-B<br>Surv(2) |
| p = 1/8 | (ND + 2NA)<br>1 | Comm-B<br>Surv(2) |

(1) Own sensor knows that CIR is filled, but neighboring sensor does not. For that neighboring sensor, this extra message is required. This conservative assumption is made for both sensors.

(2) The surveillance message is a close out transaction that can be absorbed by a pending Comm-A.

Program CIRBUN accepts this file and processes it on a per aircraft basis, counting data link transactions for the aircraft being processed. For the purposes of this study, a transaction is defined as any complete interrogation and reply cycle of the "standard" data link messages listed in Table 5-3. The program combines messages from all the different services for that aircraft to provide the minimal set of data link transactions to it. Thus, an ATC Comm-A message may be combined with a Comm-B message required for downlinking airborne data to yield a single Comm A/B transaction. The program also keeps track of high priority messages. ATC, CIR and threat messages are all assigned high priority. All others are normal priority messages. A compatible low priority message may sometimes be absorbed in a high priority message. Thus a low priority Comm-A may be combined with a high priority Comm-B to provide a high priority Comm A/B transaction.

The program CIRBUN then incorporates reinterrogation probabilities. It assumes a round reliability of 90% on the first interrogation in a scan and 98% on subsequent interrogations in that scan. At the conclusion of this process, the program yields a total transaction count and a high priority transaction count for the aircraft in question.

Program CIRBUN is provided all the sensor jurisdiction maps and a set of input parameters specifying a sensor of interest, and the particular failed sensor mode (if any) that it may be operating in. The program counts transactions and aircraft numbers for the various regions of interest for the particular failed sensor configuration of the sensor of interest. If the aircraft is in its primary zone, all the transactions are counted. If the aircraft is not in its primary zone, but does belong to a seam area, then (all) CIR transactions are counted. If the aircraft does not belong to these two areas, but does belong to the total area over which that sensor maintains surveillance, then a simple surveillance transaction is included for that aircraft. The transaction counts are used for updating appropriate histograms and azimuthal bin counts. The program finally compiles and outputs various aircraft and transaction counts of interest.

The snapshot of aircraft positions provided in the LAX-1100 model can be thought of as the positions detected by the sensors from one complete scan of each sensor's antenna. (Radar errors are not modelled in this study.) The programs then essentially determine the actual data link messages that would have been exchanged with each individual aircraft on that scan.

TABLE 5-3

DEFINITION OF A TRANSACTION

| Interrogation | Reply |
|---|---|
| Surveillance | Surveillance |
| Comm-A | Comm-B |

A "transaction" is any combination of an interrogation and a reply.

## 5.2 Sensor Loading

Table 5-4 shows the data link loading for each of the eight sensors in this analysis. For each sensor, the total number of DABS and ATCRBS targets in its jurisdiction are listed. Only DABS targets receive data link services; therefore counts of DABS targets are also provided. Most sensors are seen to have a total target load of about 400. As expected, about 80% of them are DABS equipped. For each sensor, transaction counts are provided for two configurations: (a) The nominal configuration, being the configuration where all eight sensors are functioning and (b) the worst configuration, resulting from the case of that neighboring sensor failure which creates the largest data link loading for the sensor of interest. Thus, the Long Beach sensor is nominally required to schedule 452 transactions in one scan. However, if its neighboring sensor at Santa Ana (sensor 2) should fail, it would have to provide data link services to some of that population also and the resulting transaction load on the Long Beach Sensor would be 536. It should be noted, that each sensor maintains surveillance tracks on all targets that it may ever have to service in case of neighboring sensor failures. Thus the total target population over which the sensor maintains surveillance (i.e. its target load) already includes all failure cases, and is thus independent of failure configurations. The total number of transactions that a sensor provides in one scan is about 500, when all sensors are functioning. In case of a failure of a neighboring sensor, however, a sensor may have to provide up to about 700 transactions. As for target loads, the Los Angeles International sensor is the only one that is required to maintain tracks on about 500 aircraft. All other sensors have a load of about 400 targets. The Los Angeles International sensor is so loaded because it covers for the possibility that the Burbank Sensor may fail. The topography and sensor geometry is such that if the Burbank sensor fails, most of its targets have to be accepted by the Los Angeles sensor. The deployment of another sensor in the northwest region of the basin would rectify this situation, if a reducton in Los Angeles sensor's load were desired.

Table 5-4 also lists contributions of the two most important users of the data link system, ATC and ATARS. The data link utilization by ATC is usually 3% or 4% and is never more than 7% of the total data link usage. On the other hand, ATARS accounts for a very significant portion of the data link usage. This is so, because ATC messages occur over longer time frames than ATARS. An ATC message issued once in 20 minutes contributes one transaction in 300 scans. Further, ATC messages are only issued

TABLE 5-4

SUMMARY TARGET AND TRANSACTIONS LOADS FOR LAX-1100

| Sensor | | | Targets | | Transactions Per Scan | | | Surveillance Only | Sensor Configuration* |
|---|---|---|---|---|---|---|---|---|---|
| # | Name | Abreviation | Total | DABS Equipped | Total | ATC | ATARS | | |
| 1 | Long Beach | LGB | 394 | 310 | 452 | 14 | 167 | 222 | N |
| | | | | | 536 | 19 | 262 | 173 | 2 |
| 2 | Santa Ana | SNA | 411 | 323 | 473 | 12 | 176 | 220 | N |
| | | | | | 582 | 21 | 303 | 175 | 3 |
| 3 | Ontario | ONT | 376 | 306 | 579 | 25 | 324 | 166 | N |
| | | | | | 678 | 34 | 431 | 90 | 4 |
| 4 | Norton AFB | SBD | 273 | 222 | 340 | 13 | 128 | 127 | N |
| | | | | | 449 | 26 | 262 | 51 | 3 |
| 5 | George AFB | VFV | 375 | 313 | 400 | 17 | 89 | 231 | N |
| | | | | | 456 | 32 | 149 | 157 | 6 |
| 6 | Palmdale | PMD | 375 | 313 | 374 | 15 | 69 | 235 | N |
| | | | | | 456 | 32 | 149 | 157 | 5 |
| 7 | Burbank | BUR | 325 | 255 | 475 | 17 | 241 | 105 | N |
| | | | | | 544 | 30 | 310 | 49 | 8 |
| 8 | Los Angeles International | LAX | 509 | 389 | 506 | 17 | 137 | 298 | N |
| | | | | | 676 | 29 | 309 | 190 | 7 |

* N = Nominal; number indicates failing sensor

to controlled aircraft (i.e. IFR, and controlled VFR aircraft), which account for only about half the population in LAX-1100. In contrast to this, every DABS equipped aircraft is eligible to receive ATARS messages and ATARS messages require a refresh every scan. This study uses generous growth assumptions for ATC services (see Reference 1). It is apparent that a growth of ATC services even beyond that assumed in this study can be accommodated without substantially adding to the utilization of the DABS data link.

The highest average number of data link transactions per equipped aircraft is 2.2 in the case of Ontario with the Norton sensor failing. It may be as low as 1.0, as in the case of Palmdale in its nominal configuation. It should be realized that surveillance alone requires one transaction per DABS equipped aircraft. A Comm-A, which includes surveillance, can be uplinked in place of a surveillance interrogation without any impact on data link (see Reference 1). Thus, even in the worst case, about one extra transaction per target (averaged over the population) is sufficient to provide all services that the DABS data link is expected to deliver on a tactical basis.

Finally, Table 5-4 shows the number of surveillance-only transactions for each sensor. For example, 222 out of the total of 452 transactions for the Long Beach sensor are surveillance transactions. This means that 222 out of its 310 DABS equipped targets are receiving no Comm-A or Comm-B messages. They are only receiving surveillance interrogations. Surveillance-only transactions occur for two reasons. A target may be within a sensor's primary zone and not be receiving any Comm-A or Comm-B messages; or, it may be outside its primary or seam areas, and thus only be eligible for a surveillance transaction from this sensor, even though it may receive data link messages from another sensor. It can be seen that about half of all transactions are usually surveillance only. This percentage can be as high as 63%, as in the case of Palmdale, but it is also seen to be as low as 9%, as in the case of Burbank (with LAX failing.) The number of surveillance-only transactions is always reduced in a failed sensor configuration because, in that case, some of its surveillance-only targets which lie outside its primary zone begin to receive data link services from this particular sensor in order to cover for the failed sensor. The surveillance-only transaction data can be used to compute the average number of transactions received by those aircraft that actually receive some data link messages. Thus, for the case of Long Beach (nominal) there are a total of (452-222) = 230 non-surveillance transactions. 88 aircraft receive these 230 transactions giving an average of 2.6. The highest such average occurs for Santa Ana (with Ontario failing) and is 2.8.

## 5.3 Peaking Phenomena

DABS system designers need to know peak loads on a DABS sensor. Processing requirements are strongly determined by the peak target and data link requirements since the sensor works on the basis of a rotating beam and most of its tasks are performed in units of 11.25° azimuth sectors. Table 5-5 presents peak loading numbers for LAX-1100 sensors. It shows target count peaks as well as message volume peaks. It may be remarked that the peak message rate for a sensor does not necessarily coincide with its peak target count, whether considering beam dwells or sectors. It is seen that the absolute worst peak beam dwell consists of a total of 15 aircraft (12 of them equipped) for the Palmdale sensor. The total aircraft load on the Palmdale sensor is 375 aircraft or an average of 2.5 aircraft per beam dwell. Thus, the peak beam dwell is six times as dense as the average beam dwell as far as target density is concerned. Total transactions in a beam dwell may be as high as 29. The densest sector contains 52 aircraft, 44 of them being equipped. A sector may experience up to 94 transactions. A 90° quadrant may contain up to a maximum of 255 targets. Finally, Table 5-5 shows that a single aircraft may need to be interrogated up to as many as eight times in one scan (i.e., one beam dwell) for the necessary services. Peak loading is quite important to system design and Section 5.5 is devoted to taking a closer view of peak transactions with single aircraft.

## 5.4 Extended Length Messages (ELMs)

The set of services listed in Chapter 3 make a meager use of ELMs. Table 3-3 showed a use of about 10 ELMs of various lengths in an hour per DABS equipped aircraft. This gives a probability of about one ELM every 100 scans to an aircraft. With at most 12 DABS equipped aircraft in a beam dwell, most beam dwells don't have an ELM scheduled. With at most 202 DABS equipped aircraft in a 90° quadrant, there are at most about two ELMs in a quadrant scheduled. ELMs thus form a very small portion of the total requirements and are not analysed further in this chapter. The ELM capability of DABS, however, does offer a growth potential. This is discussed in Chapter 8.

## 5.5 Transactions to Single Aircraft

Table 5-6 shows a histogram of total transactions to individual aircraft in LAX-1100. All the aircraft are taken into account

## TABLE 5-5

## SUMMARY OF TARGET AND TRANSACTION PEAKING IN LAX-1100

| # | Sensor | Maximum Number of Targets Experienced In Different Azimuthal Areas: 90° (Quadrant) Total | 90° (Quadrant) DABS Equipped | 11.25° (Sector) Total | 11.25° (Sector) DABS Equipped | 2.4° (Beam Dwell) Total | 2.4° (Beam Dwell) DABS Equipped | Transactions(1): Most In A Beam Dwell | Most In A Sector | Most To An Aircraft |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | LGB | 183 | 142 | 33 | 30 | 12 | 10 | 25 | 47 | 6 |
| 2 | SNA | 225 | 178 | 46 | 37 | 12 | 12 | 26 | 91 | 8 |
| 3 | ONT | 128 | 85 | 28 | 22 | 8 | 7 | 22 | 56 | <u>8</u> |
| 4 | SBD | 130 | 105 | 27 | 22 | 10 | 8 | 16 | 44 | 7 |
| 5 | VFV | 202 | 108 | 44 | 36 | 13 | 11 | 19 | 53 | 5 |
| 6 | PMD | 202 | 176 | <u>52</u> | <u>44</u> | <u>15</u> | <u>12</u> | <u>29</u>(2) | 75 | 5 |
| 7 | BUR | 156 | 116 | 26 | 23 | 9 | 8 | 22 | 62 | 8 |
| 8 | LAX | <u>255</u> | <u>202</u> | 47 | 38 | 13 | 11 | 26 | <u>94</u> | 7 |

(1) Peak numbers for any configuration of the sensor
(2) 7 of these transactions contain Comm-B replies
(3) The highest number within each column is underlined

TABLE 5-6

HISTOGRAM OF TRANSACTIONS TO INDIVIDUAL AIRCRAFT IN LAX-1100

| Number of Transactions | Number of Aircraft | Cumulative Percentage |
| --- | --- | --- |
| 0 | 233 | 21.1% |
| 1 | 324 | 50.0% |
| 2 | 257 | 73.7% |
| 3 | 145 | 86.8% |
| 4 | 76 | 93.7% |
| 5 | 44 | 97.7% |
| 6 | 17 | 99.2% |
| 7 | 6 | 99.7% |
| 8 | 3 | 100.0% |
| TOTAL | 1105 | |

at once, without regard to any particular sensor. In actuality, of course, overlapping portions of this population are serviced by each of the eight sensors. Thus, this histogram does not reflect the actual loading for any one sensor. However, it does provide an indication of an overall distribution of transactions for aircraft. 50% of the aircraft require multiple transactions. Nearly 13% of the aircraft require more than three transactions and three aircraft in the entire population require eight transactions. In other words, sensors serving any one of these three aircraft for data link would be required to be capable of delivering up to eight transactions to an aircraft.

Table 5-7 lists the three aircraft requiring eight transactions and the sources of those transactions. It also lists ATARS advisories for each aircraft. For example, aircraft VLGB086 has three ATARS proximity advisories and two ATARS threat advisories. Both the threats are due to DABS aircraft and also cause resolution advisories. The three proximities contribute two transactions (since two proximities are packed in one Comm-A), the two threats contribute two transactions (at one threat per Comm-A) and the resolution advisories on the two DABS aircraft require a two-row CIR, resulting in two transactions. Thus ATARS accounts for six transactions to this aircraft. Other services, such as uplink of ground data, contribute two more transactions, resulting in a total of eight transactions for this aircraft. Of these eight transactions, four are high priority, for CIR and threats.

ATARS/BCAS coordination logic has been changed since the performance of this analysis. The CIR concept, which requires multiple transactions for a full coordination, is no longer used. In its place, a concept called the Resolution Advisory Register (RAR) has been incorporated (Reference 2). The RAR requires a single Comm-A/Comm-B transaction for the coordination of a conflict. Thus, with this new coordination logic aircraft, VLGB086 would require only one transaction for conflict coordination, rather than two as in Table 5-7. This would reduce the total number of transactions required for that aircraft to seven.

The other two aircraft, however, only have one transaction due to the CIR. Thus, the new (RAR) formats which use a single transaction for ATARS/BCAS coordination will not effect a reduction in transaction numbers for these two aircraft. (The major contributors for multisite transactions for these two aircraft are threats and proximities.) Thus, even with the use of the new RAR formats, which usually place lower requirements

TABLE 5-7

ANATOMY OF MULTIPLE (8) TRANSACTIONS TO INDIVIDUAL AIRCRAFT

| Aircraft ID | Number Of ATARS Advisories | | | | Number Of Transactions Due To | | | | | | Total Number Of Transactions (With CIR) | Total Number Of Transactions If RAR* Is Used Instead of CIR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Requiring Resolutions Against | | Threats | Proximities | CIR | Threats | Proximities & Overhead | ATC | Other | Reinterrogation | | |
| | N DABS Aircraft Where N = | N ATCRBS Aircraft Where N = | | | | | | | | | | |
| VLGB086 | 2 | 0 | 2 | 3 | 2 | 2 | 2 | 0 | 2 | 0 | 8 | 7 |
| VIGB031 | 1 | 0 | 3 | 3 | 1 | 3 | 2 | 1 | 1 | 0 | 8 | 8 |
| VIGB358 | 1 | 0 | 2 | 2 | 1 | 2 | 2 | 1 | 1 | 1 | 8 | 8 |

*RAR is the current ATARS/BCAS coordination concept. See Reference 2.

on the data link, DABS sensors would be required to serve a single aircraft up to eight times in a single beam dwell in LAX-1100.

This count of eight includes reinterrogation (for example, see aircraft VIGB358). Thus, as long as the sensor can schedule eight interrogations, all services required to be delivered by it on a tactical basis can be provided.

Table 5-8 lists the aircraft requiring four Comm-B transmissions and one aircraft (amongst others) requiring three Comm-B transmissions in one scan. Of the four Comm-Bs transmitted by VIGC084, two are due to the CIR protocol. With the RAR concept, that number would be reduced to one, resulting in only three Comm-Bs from VIGC084. Thus, with the RAR protocol, the requirement for multiple Comm-Bs would be reduced to a maximum of three Comm-Bs rather than a maximum of four Comm-Bs as with the CIR protocol.

Some of these messages are high priority, i.e., they must be delivered each scan. Others like uplink of ground data can, if necessary, be delayed and queued on a later scan for delivery without a significant impact on the service. The next section identifies the contribution of high priority messages.

## 5.6 High Priority Transactions

Table 5-9 compares the histograms of "all" transactions (i.e., high or low priority transactions) and high priority transactions alone. The CIR, threat, ATC and surveillance transactions are high priority transactions. Every DABS aircraft receives at least one high priority transaction for surveillance. (ATCRBS aircraft of course receive no DABS transactions; they receive four ATCRBS interrogations.) Table 5-9 shows that no aircraft in the basin requires more than five high priority transactions in one scan.

Table 5-9 also shows the number of aircraft requiring Comm-Bs (high priority Comm-Bs and either-priority Comm-Bs). Thus, 156 aircraft have transactions such that one of their transactions involve a Comm-B downlink. 895 aircraft involve no Comm-Bs. Table 5-9 shows that there exists an aircraft requiring up to four high priority Comm-B replies.

With the CIR concept replaced by the RAR concept, the maximum number of high priority Comm-Bs required for a single aircraft would be reduced to three. This can be seen from Table 5-8. Aircraft VIGC084 would require one transaction each for RAR and

TABLE 5-8

ANATOMY OF MULTIPLE COMM-B REPLIES FROM INDIVIDUAL AIRCRAFT

| Aircraft ID | Number of Comm-Bs Due to | | | | Total Number of Comm-Bs (with CIR) | Total Number of Comm-Bs if RAR* Used Instead of CIR |
|---|---|---|---|---|---|---|
| | CIR | ATC | Other | Reinterrogations | | |
| VIGC084 | 2 | 1 | 0 | 1 | 4 | 3 |
| VIMD002 | 0 | 1 | 1 | 1 | 3 | 3 |

*The RAR is the current ATARS/BCAS coordination concept. See Reference 2.

TABLE 5-9

COMPARISON OF TOTAL AND HIGH PRIORITY TRANSACTIONS IN LAX-1100

| | Aircraft Receiving N Transactions Where N = | | | | | | | | | Aircraft Transmitting N Comm-Bs Where N = | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 0 | 1 | 2 | 3 | 4 |
| High or Low Priority Transactions | 233* | 324 | 257 | 145 | 76 | 44 | 17 | 6 | 3 | 895 | 156 | 48 | 5 | 1 |
| High Priority Transactions Only | 233* | 699 | 119 | 34 | 17 | 3 | 0 | 0 | 0 | 913 | 152 | 35 | 4 | 1 |

*ATCRBS aircraft

ATC, both being high priority. The reinterrogation would therefore also need to be high priority, thus yielding a total of three high priority Comm-Bs. Introduction of the RAR concept would not impact the maximum number of high priority Comm-As. This is seen from Table 5-7. Aircraft VIGB031 would still require five high priority transactions (one for resolution, three for threats and one for ATC).

## 5.7 ATARS Messages

As seen in Table 5-4, ATARS advisories are often the single largest contributor to DABS data link activity. Table 5-10 reviews these results and provides a further breakdown of ATARS messages into the contributions from its proximities, threats and the CIR. It is seen that in the nominal configurations (i.e., when all sensors are functioning) ATARS may account for up to 56% of the total data link transactions as in the case of the Ontario Sensor. It may, on the other hand, account for as little as 18% of the total load, as in the case of Palmdale. The Ontario sensor is situated in an area of sparse traffic. The ATARS contribution is, as may be expected, a function of traffic density. In sparse traffic, most of the activity is for surveillance purposes. In dense traffic, as much as 63% of the total message volume may be due to ATARS, as in the case of Ontario, with Norton failing. More than 50% of the ATARS messages are from proximities. Thus, again, in the case of ONT (SBD failing), 288 of a total of 431 ATARS messages are from proximities. Threats account for about 15% of the total ATARS activity. For most sensors the CIR contributes about 10% of the total data link activity and is never more than 15% (as in the case of SNA: 83/582 = 14%).

Thus, the CIR contributes to only a small portion of the total data link load. It does contribute to an increase in the incidence of multiple Comm-A and Comm-B transactions. However, as seen in the previous section, even without the CIR, the requirements on DABS to deliver eight Comm-As to a single aircraft would remain.

Table 5-11 shows the distribution of ATARS advisories for the entire population in LAX-1100. It is seen that about 50% of the aircraft (506 of 1105) receive no ATARS traffic advisories. Three aircraft receive up to eight ATARS traffic advisories, the maximum number possible within ATARS formats. Sixteen percent of the aircraft receive threat advisories. No aircraft receives more than three threat advisories at one time. A total of 68 aircraft (6% of the total) are in conflict situations. Five of these 68 aircraft have two aircraft simultaneously in conflict with them.

TABLE 5-10

ATARS TRANSACTIONS IN LAX-1100

| # | Sensor | Sensor Failing | ATARS Transactions | | | | Total Trans-actions For Sensor For Scan | % Of Total Trans-actions | Total Aircraft Receiving ATARS Messages |
|---|---|---|---|---|---|---|---|---|---|
| | | | Prox-imities | Threats | CIR | Total ATARS | | | |
| 1 | LGB | 2 | 163 | 35 | 64 | 262 | 536 | 49% | 126 |
| | | N | 101 | 26 | 40 | 167 | 452 | 37% | 78 |
| 2 | SNA | 3 | 175 | 45 | 83 | 303 | 582 | 52% | 126 |
| | | N | 99 | 20 | 57 | 176 | 473 | 37% | 85 |
| 3 | ONT | 4 | 288 | 79 | 64 | 431 | 678 | 63% | 187 |
| | | N | 196 | 64 | 64 | 324 | 579 | 56% | 128 |
| 4 | SBD | 3 | 195 | 42 | 25 | 262 | 449 | 58% | 141 |
| | | N | 103 | 16 | 9 | 128 | 340 | 38% | 74 |
| 5 | VFV | 6 | 88 | 31 | 30 | 149 | 456 | 33% | 96 |
| | | N | 42 | 20 | 27 | 89 | 400 | 22% | 48 |
| 6 | PMD | 5 | 88 | 31 | 30 | 149 | 456 | 33% | 96 |
| | | N | 46 | 11 | 12 | 69 | 374 | 18% | 52 |
| 7 | BUR | 8 | 206 | 58 | 46 | 310 | 544 | 57% | 159 |
| | | N | 156 | 49 | 36 | 241 | 475 | 51% | 171 |
| 8 | LAX | 7 | 178 | 56 | 75 | 309 | 673 | 46% | 159 |
| | | N | 66 | 16 | 55 | 137 | 506 | 27% | 74 |

* N = Nominal Configuration

TABLE 5-11

HISTOGRAM OF ATARS ADVISORIES TO AIRCRAFT IN LAX-1100

| Number Of Intruders | Conflict | Threats (Only) | Proximities (Only) | Threats Or Proximities |
|---|---|---|---|---|
| 0 | 1037 | 929 | 537 | 506 |
| 1 | 63 | 136 | 256 | 237 |
| 2 | 5 | 34 | 155 | 147 |
| 3 | 0 | 6 | 83 | 100 |
| 4 | 0 | 0 | 41 | 60 |
| 5 | 0 | 0 | 24 | 32 |
| 6 | 0 | 0 | 5 | 15 |
| 7 | 0 | 0 | 3 | 5 |
| 8 | 0 | 0 | 1 | 3 |
| Total Number of Aircraft | 1105 | 1105 | 1105 | 1105 |

Table 5-12 shows the intruder composition for these 68 conflict situations. It shows that 16 aircraft have a single DABS intruder and 47 aircraft have a single ATCRBS intruder. Four aircraft experience two ATCRBS intruders simultaneously. There are no conflicts with more than two intruders. The number of aircraft with ATCRBS intruders is higher because ATARS provides larger look ahead times to the equipped aircraft in case of unequipped intruders.

TABLE 5-12

INTRUDER EQUIPAGE TYPE IN ATARS CONFLICTS

| Intruder Type | Number of Aircraft |
|---|---|
| One DABS Intruder | 16 |
| One ATCRBS Intruder | 47 |
| One DABS and One ATCRBS Intruder | 1 |
| Two ATCRBS Intruders | 4 |
| Total | 68 |

# 6. SENSITIVITY TO TRAFFIC DENSITY

The results in Chapter 5 have been obtained with the LAX-1100 model. This model represents the best estimate of the traffic that may be encountered in the Los Angeles basin in the year 1995. It is, however, of interest to determine the sensitivity of sensor loading to traffic densities. First of all it is necessary to know the impact on the sensor loading if the traffic density in the Los Angeles basin should be significantly different than that assumed here. Secondly, traffic in different parts of the country is not expected to be as high as that in the Los Angeles basin. For this reason, analysis was conducted for two other traffic models approximately 50% denser and 50% sparser than the nominal LAX-1100 model.

The traffic model of Reference 9 from which LAX-1100 has been derived contains 1840 aircraft. This was used as the high density model and is called LAX-1840. Another model was created to yield a total of 600 aircraft by deleting, in appropriate proportions, aircraft from LAX-1100. This low density model is called LAX-600. The eight sensor deployment used for LAX-1100 was also used for these two alternate models and the analysis described in Chapter 5 was also conducted for both alternate models. (See Appendix A for a complete description of these alternate models.)

Figure 6-1 shows the variation in total and DABS equipped targets for the most heavily loaded sensor for each traffic model. Figure 6-1 also shows the maximum number of DABS equipped targets that may be encountered in any 2.4$^{\circ}$ beam dwell for any of the eight sensors. It is seen that the maximum target load for a sensor varies linearly with the total aircraft count in the model. The maximum target load in the peak beam dwell is also very nearly proportional to the total aircraft count in the model. It is seen that the high density model contains over 800 targets for a sensor and presents as many as 20 DABS equipped targets in the peak beam dwell.

Figure 6-2 shows the variation with the model of the maximum number of transactions required to be delivered to a single aircraft. It is seen that for the low density model, the sensor must be capable of delivering at least six transactions to a single aircraft. For the high density model, the sensor must be capable of delivering up to 12 transactions to a single aircraft. Figure 6-2 also shows the variation of the maximum number of transactions that may need to be scheduled in a beam dwell. It shows that for the high density model, as many as 65 transactions may need to be scheduled in a 2.4$^{\circ}$ beam dwell.

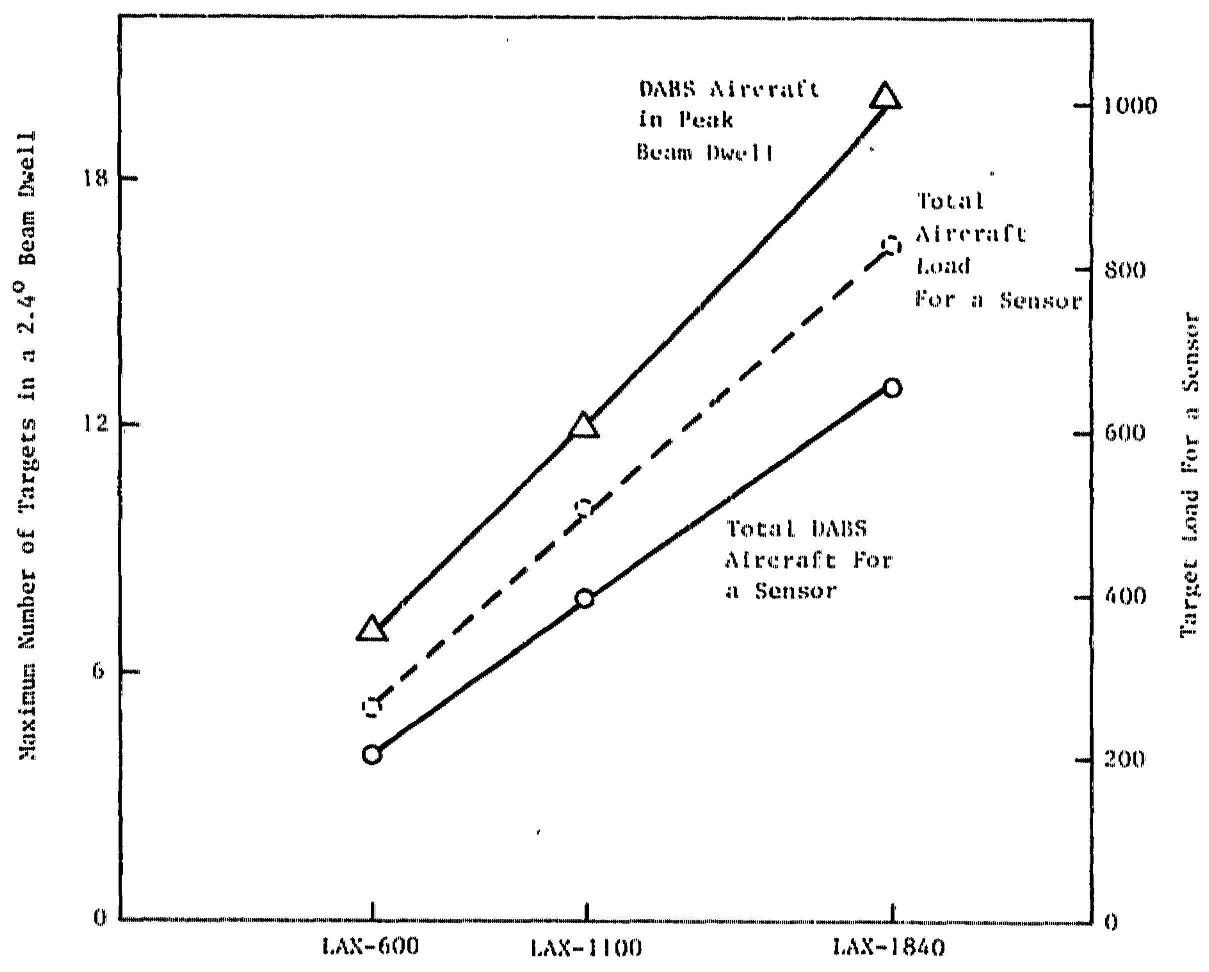



**FIGURE 6-1**
**MAXIMUM TARGET LOADS AS FUNCTION OF TRAFFIC MODEL**

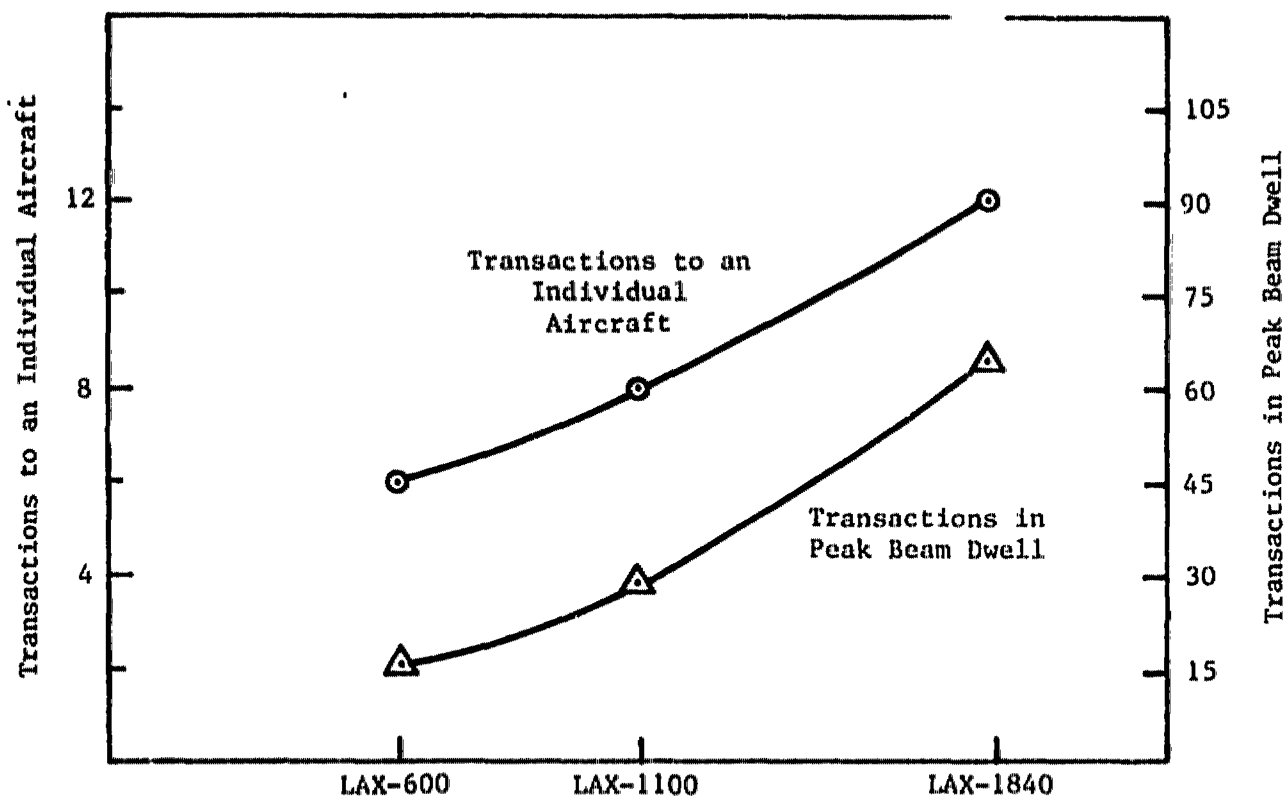



**FIGURE 6-2**
**PEAK TRANSACTIONS AS A FUNCTION OF TRAFFIC MODEL**

Although not shown in the figure, nine of these involve Comm-B replies, and 32 of the 65 total transactions are high priority.

The transaction requirements placed by the high density model are somewhat high. The necessity of scheduling 12 transactions in one beam dwell to a single aircraft places a significantly higher demand on the computational power of the sensor than the eight transactions required by the nominal traffic model (LAX-1100). Appendix C shows the total time line capacity of a DABS sensor for 20 targets in a 50 nmi range to be about 80 transactions in a beam dwell. Thus, the total beam dwell transaction requirement (65 Comm-As and 9 Comm-Bs) nearly saturates the sensor channel capacity.

These results prompt a closer look at the 1840 aircraft model. Figure 6-3 shows the largest cluster of aircraft in LAX-1840 in which each aircraft shown in the figure produces an ATARS advisory for the subject aircraft (IIGC023, shown at the center). The figure shows that there are a total of 18 aircraft in the vicinity of the subject aircraft that produce ATARS traffic advisories, six of which are "threats". In a dense airspace such as this, ATARS parameters would probably be desensitized to some extent. In fact, ATARS currently chooses only the most important eight of these 18 to be displayed to the pilot. The most important conclusion from this picture, however, is not the need for ATARS desensitization; it pertains, rather, to the unrealistic densities of the model itself. In fact, there exist 54 aircraft within 2000 feet and 6 nmi of the subject aircraft IIGC023, only 18 of which are shown in Figure 6-3 because they produce ATARS advisories. Flying through such an airspace may at best be considered hazardous. The point is that if the total number of aircraft in the Los Angeles hub were to approach such magnitudes, those aircraft would likely not stay concentrated in certain areas as assumed in this model. The aircraft population would spread over a larger area, possibly even extending beyond the 60 nmi radius that defines the hub currently, so that the densities would not approach such unrealistic magnitudes.

This also addresses the question of whether the DABS system should be designed based on a model that pertains to the year 1995 (viz, LAX-1100) or to a later year model, such as the year 2005. What if by the year 2005 the Los Angeles hub air traffic should resemble LAX-1840? The summary contention of the argument presented here is that LAX-1840 is an inadequate model to describe the distribution of traffic in the Los Angeles basin even if the total traffic in the basin should in fact increase to the levels assumed therein (i.e., 1840 aircraft). The

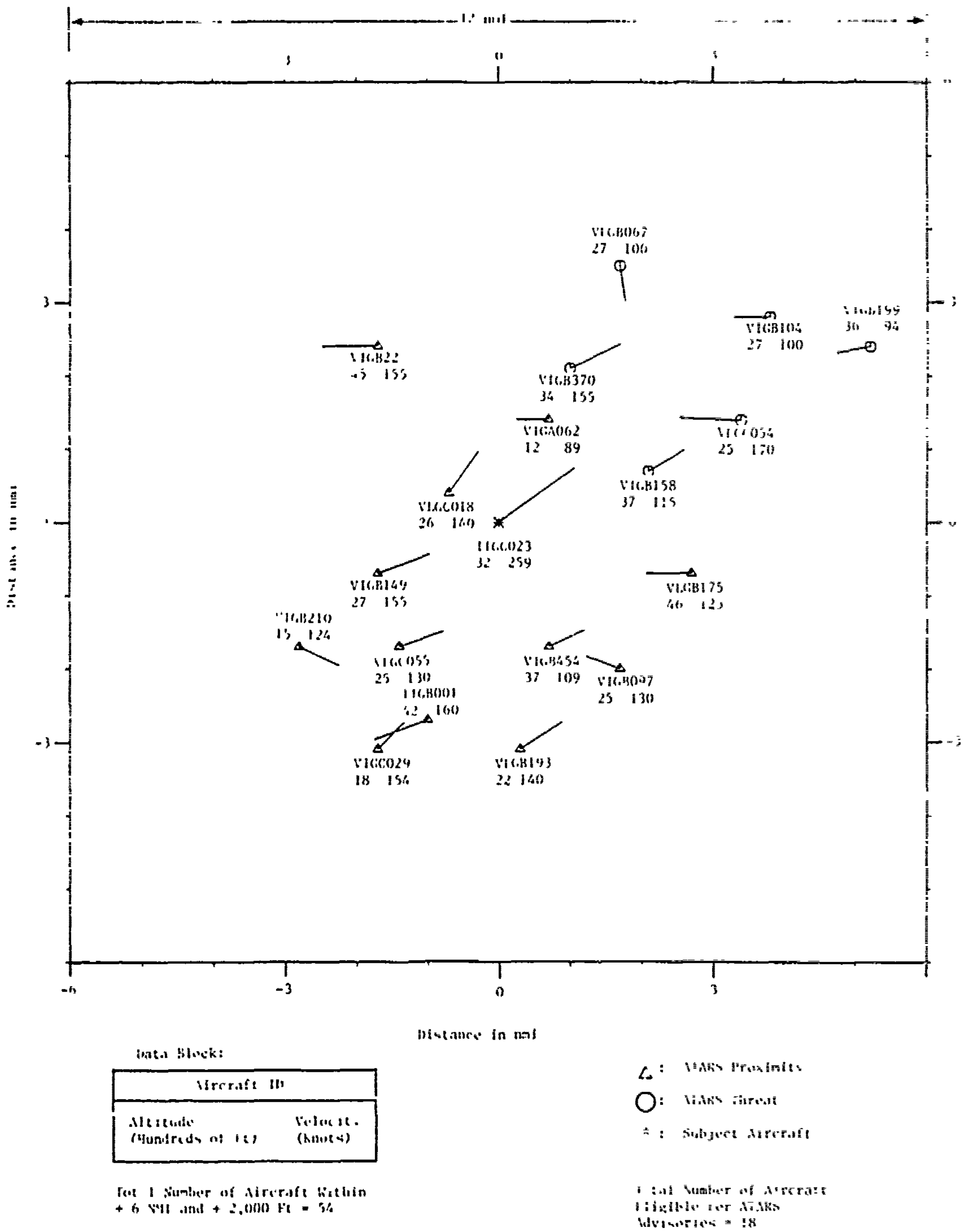



**FIGURE 6-3**
**WORST AIRCRAFT CLUSTER IN LAX-1840**

LAX-1840 model assumes the growth to be geographically constrained in such ways as to produce unrealistically high traffic densities. If the total number of aircraft did approach 1840, causing the traffic to spread out more, more sensors should also be deployed to service that environment. Deployment of additional sensors reduces the requirements on each sensor. (This is described in greater detail in Chapter 8.) Thus designing DABS on an eight sensor coverage map of LAX-1840 as assumed in the high density deployment here is not appropriate.

Finally, Appendix A shows that LAX-1840 is in fact no longer a valid forecast for the Los Angeles basin for the year 1995. The forecasts leading to LAX-1840 are now over seven years old. Current forecasts yield a considerably smaller growth. Designing DABS to the requirements of LAX-1840 is thus an unrealistic exercise, accompanied by the significant cost impacts of a design requiring considerably higher computing power than that necessary. The LAX-1100 model provides a more realistic scenario of the worst traffic densities that DABS may ever encounter. It is recommended that the FAA should plan to introduce more sensors into the Los Angeles basin if traffic levels increase beyond those in the LAX-1100 model, rather than design a DABS sensor capable of handling the LAX-1840 model with eight sensors.

Figure 6-2 shows that for the low density model, the sensor should be capable of providing up to six transactions to a single aircraft. Reference 13 shows a peak instantaneous airborne count of 485 aircraft in the 1972 Los Angeles basin. Thus, the requirements to serve the LAX-600 model would appear to place the lower limits on the nominal DABS sensor requirements.

Table 6-1 shows the number of conflicts in each of the three models. It is included in this chapter for the sake of completeness of this sensitivity study. Number of conflicts increase nearly in proportion to the square of the increase in the number of aircraft. There are no conflicts involving more than three aircraft in any model. The nominal model (LAX-1100) contains five 3-aircraft conflicts. LAX-600 contains only 2-aircraft conflicts.

TABLE 6-1

NUMBER OF CONFLICTS FOR L.A. BASIN TRAFFIC MODELS

| Model | Number and Type of Intruders | | | | | Total Number of Conflicts |
|---|---|---|---|---|---|---|
| | 1 DABS | 1 ATCRBS | 1 DABS & 1 ATCRBS | 2 ATCRBS | 2 DABS | |
| LAX-600 | 2 | 11 | 0 | 0 | 0 | 13 |
| LAX-1100 | 16 | 47 | 1 | 4 | 0 | 68 |
| LAX-1840 | 46 | 122 | 10 | 9 | 5 | 192 |

# 7. DABS SENSOR CAPACITY REQUIREMENTS

Section D.1 shows the capacity specifications written in 1974 for the DABS engineering models (Reference 14). Some of these 1974 specifications are consistent with the loading requirements found in this analysis. Thus, most sensors in this analysis are found to yield a total load of about 400 aircraft and a peak sector load of about 50 targets. (See Tables 5-4 and 5-5.) However, several other items in these specifications are inconsistent with this analysis. Thus, the 1974 specifications only require a maximum of three transactions to an aircraft, whereas this analysis clearly shows the need for up to eight transactions to some of the aircraft. The 1974 specifications indicate target peaks of up to 32 targets in a $2.4^{o}$ beam dwell whereas this analysis shows that no more than 15 targets are ever seen in a beam dwell. Such differences are to be expected because major services such as ATARS are only now understood well enough so that their loading requirements can now be identified clearly. This could not have been done in 1974. Also, this study carries out a very precise and detailed analysis of LAX-1100, whereas the earlier specifications were obtained by broad assumptions based on the LAX-1840 model. Since the DABS procurement process is still underway, it is useful to identify a more exact set of specifications on the basis of this more precise understanding. Section 7.1 provides a general discussion of issues and supporting data relating to writing DABS capacity specifications. Section 7.2 contains the recommended specifications. Section 7.3 contains a comparison of the various existing DABS sensor capacity specifications and finally section 7.4 provides relevant information for use in ATARS processing specifications.

## 7.1 Discussion

### 7.1.1 Target Capacities

Most sensors in this analysis show a maximum target load of about 400 targets. (See Table 5-4.) Only the LAX sensor shows a target load of about 500 targets, resulting from the requirement to cover for a failed Burbank sensor. A sensor in the northwest region of the basin would prevent the LAX sensor from having to handle such large loads. Alternately, the LAX sensor may be provided an expanded sensor with a somewhat higher target capacity than the nominal sensor. It is recommended that a nominal load of about 400 targets be specified for DABS sensors, expandable to 700 targets. Many areas in the country will not, however, require even a 400 target capacity. The LAX-600 model shows the need for a target loading of 250. It is recommended that this number be used for procuring a low density DABS sensor.

### 7.1.2 Mix

All targets in a population will probably never be DABS equipped. The mature population projections of this study show about an 80% DABS equipage ratio. In the early days of the deployment, on the other hand, most targets would be ATCRBS equipped.

### 7.1.3 Peak Target Loads

At most, 52 targets are seen in an 11.25° sector. A number 50 is recommended. The worst case of target peaking in successive sectors involved four consecutive sectors with 35, 33, 47 and 33 targets respectively. An ability to handle four successive peak sectors is recommended.

The LAX sensor shows a maximum of 255 targets in a quadrant, whereas the SNA sensor shows up to 225 targets in a quadrant. A peaking specification of 250 targets in a 90° quadrant is considered adequate.

The maximum target load in a beam dwell is 15. Two successive azimuthal peaks with 15 targets were not found any where in the analysis, but may be included as a conservative measure. The worst case of successive peaks involved three successive beam dwells with 15, 10 and 13 targets respectively. Of these, 12, 10 and 12 targets respectively were DABS equipped.

### 7.1.4 Transactions to Aircraft

Table 5-5 shows that up to eight transactions for data transfer are required to a single aircraft. Each beam dwell consists of four DABS periods. Thus, two transactions per DABS period are required for the nominal (400 target) sensor. Analysis of LAX-600 shows the need for up to six transactions to one aircraft. (See Figure 6-2.) Thus, the low density (250 target) sensor would also have to be capable of scheduling two transactions per DABS period for at least two of the DABS periods. The requirement for multiple schedules in a DABS period has computing power implications for the scheduler. Since the low density sensor would have to satisfy those requirements in some of the periods, placing an eight-transaction requirement on the low sensor does not seem to imply an additional requirement. Thus, the eight transaction requirement should be maintained for all sensors.

Tables 7-1 and 7-2 show some of the most demanding beam dwells and sectors as far as multiple transaction requirements are

TABLE 7-1

SAMPLE HISTOGRAMS OF PEAK MULTIPLE TRANSACTIONS WITHIN 2.4° BEAM DWELLS

| Description of Beam Dwell | | Number of Aircraft In Beam Dwell | | Total Number of Transactions In Beam Dwell | Number of Aircraft Receiving N Transactions Where N = | | | | | | | | | Number of Aircraft Transmitting N Comm-Bs Where N = | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Site | Beam Dwell Number | Total | DABS | | 0* | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 0 | 1 | 2 | 3 | 4 |
| LGB | 148 | 8 | 7 | 25 | 1 | 2 | 0 | 2 | 0 | 2 | 0 | 1 | 0 | 7 | 0 | 1 | 0 | 0 |
| LAX | 45 | 13 | 11 | 26 | 2 | 5 | 2 | 1 | 1 | 2 | 0 | 0 | 0 | 10 | 2 | 1 | 0 | 0 |
| LAX | 57 | 3 | 2 | 8 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 1 |
| ONT | 61 | 5 | 5 | 20 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 3 | 1 | 1 | 0 | 0 |
| ONT | 82 | 4 | 4 | 18 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 2 | 0 | 1 | 1 | 0 |
| ONT | 147 | 6 | 6 | 21 | 0 | 0 | 2 | 0 | 3 | 1 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 |
| ONT | 69 | 6 | 5 | 17 | 1 | 3 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 4 | 0 | 2 | 0 | 0 |
| LGB | 26 | 8 | 8 | 12 | 0 | 5 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 5 | 3 | 0 | 0 | 0 |
| PMD | 143 | 14 | 12 | 29 | 2 | 3 | 3 | 5 | 0 | 1 | 0 | 0 | 0 | 10 | 1 | 3 | 0 | 0 |

*ATCRBS targets do not receive DABS interrogations. They receive four ATCRBS interrogations.

TABLE 7-2

SAMPLE HISTOGRAMS OF PEAK MULTIPLE TRANSACTIONS WITHIN 11.25° SECTORS

| Description of Sector | | Number of Aircraft in 11.25° Sector | | Total Number of Transactions in Sector | Number of Aircraft Receiving N Transactions Where N = | | | | | | | | | Number of Aircraft Transmitting N Comm-Bs Where N = | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Site | Sector Number | Total | DABS | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 0 | 1 | 2 | 3 | 4 |
| ONT | 15 | 28 | 22 | 49 | 6 | 15 | 2 | 1 | 0 | 0 | 2 | 1 | 1 | 22 | 2 | 4 | 0 | 0 |
| LAX | 10 | 47 | 38 | 94 | 9 | 15 | 9 | 4 | 4 | 4 | 1 | 1 | 0 | 39 | 5 | 3 | 0 | 0 |
| LAX | 11 | 37 | 32 | 74 | 5 | 10 | 12 | 4 | 2 | 4 | 0 | 0 | 0 | 27 | 7 | 3 | 0 | 0 |
| LAX | 12 | 25 | 19 | 37 | 6 | 9 | 5 | 4 | 0 | 0 | 1 | 0 | 0 | 22 | 2 | 0 | 0 | 1 |

concerned. Thus, in Table 7-1, beam dwell # 61 for the Ontario sensor contains five DABS targets. Three of these targets require eight, seven and three transactions respectively and the remaining two targets require one transaction each, leading to a total of 20 transactions in the beam dwell. Two of these aircraft are also seen to be downlinking Comm-Bs: one aircraft transmits two Comm-Bs and the other transmits one Comm-B. (In other words, three of the 20 transactions include Comm-B replies.) Beam dwell # 57 for LAX shows that up to four Comm-Bs may be required to be delivered to a single aircraft.

Due to the four DABS-periods structure of each beam dwell, it is recommended that transaction requirements be specified in multiples of four transactions. Table 7-1 is used as a guideline for establishing the maximum transaction requirements for a beam dwell. An approximate "envelope" approach is taken as follows. The most number of aircraft requiring five, six, seven or eight transactions for any one beam dwell are all counted as requiring eight transactions. Beam dwell #82 for the ONT sensor yields three aircraft in this category. The most aircraft requiring two, three or four transactions in any beam dwell are counted to be receiving four transactions each. Beam dwell #143 for the PMD sensor yields eight aircraft in this category. However, this beam dwell contains only one aircraft receiving five Comm-As. The specification just formulated guarantees eight transactions each to three aircraft, thus assuring the building of eight schedules. Therefore, in the interest of not overspecifying the sensor, only five additional aircraft are assumed to require the delivery of four Comm-As each. Since no more than 12 DABS aircraft are seen in any beam dwell the four remaining DABS aircraft are assumed to require one transaction each.

These resulting peak beam dwell requirements are summarized in Table 7-3. Comm-B requirements are also included, and show the need for a maximum of four Comm-B replies for one aircraft in the peak beam dwell. As shown earlier in Section 5.5, the analysis only shows the need for a maximum of three Comm-Bs when the RAR, instead of the CIR, is considered. However, this does not include the possibilities of the RAR being "busy" during a ground interrogation. This can occur due to an ongoing BCAS to BCAS coordination. The expected durations of such "RAR busy" conditions are not currently known. It is therefore not possible to estimate the number of additional interrogations that may be required. One extra interrogation is here assumed to be sufficient, thus increasing the number of required Comm-B transmissions for an aircraft to a maximum of four.

TABLE 7-3

PEAK TRANSACTION REQUIREMENTS FOR DABS SENSORS

| Type of Peaking | Requirements | | | | | | | | | Implied Totals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number of Targets (DABS and ATCRBS) | Number of Aircraft Receiving N Transactions Where N = | | | Number of Aircraft Transmitting N Comm-Bs Where N = | | | | | Total Targets Receiving Data Link Messages | Total Number of Transactions | Total Number of Comm-Bs |
| | | 1 | 4 | 8 | 1 | 2 | 3 | 4 | | | | |
| 2.4° Beam Dwell | 15 | 4 | 5 | 3 | 3 | 2 | 1 | 1 | | 12(1) | 48 | 14 |
| 11.25° Sector | 50 | 18 | 20 | 6 | 8 | 4 | 2 | 2 | | 44(1) | 146 | 30 |
| 90° Quadrant | 250 | 90 | 85 | 25 | 32 | 16 | 8 | 8 | | 200(2) | 630(3) | 120 |

(1) Consistent with number of DABS aircraft in Table 5-5.
(2) 80% of 250.
(3) The transactions count of 630 is for the peak quadrant. The maximum transaction count for a 400 aircraft sensor is obtained by considering a peak quadrant (250 targets) together with three peak sectors (50 targets each). Such a combination yields the maximum transaction count of $630 + 3 * 146 = 1068$ transactions for a scan.

Sector peaking requirements shown in Table 7-3 are obtained by using Table 7-2 as a guideline. Since two peak beam dwells may occur consecutively (Section 7.1.3), and a single $11.25^{o}$ sector contains four $2.4^{o}$ beam dwells, sector requirements must be consistent with the possibility of an occurrence of two peak beam dwells within the peak sector. The Comm-B requirements for the peak sector are a result of this constraint.

Table 7-4 shows examples of peak transaction and target loading for $90^{o}$ quadrants. Recommended quadrant peaking requirements in Table 7-3 are based on information in Table 7-4 and the requirement that the sensor be able to handle up to four successive peak sectors (Section 7.1.3). (All four peak $11.25^{o}$ sectors may occur in one $90^{o}$ peak quadrant.)

Finally, Table 7-5 shows histograms of multiple transactions for each of the eight sensors. For each sensor, a histogram of transactions to its total served population is presented. Table 7-5 is included here only for the sake of completeness. At most 678 transactions per scan are actually seen to be required of a single sensor in LAX-1100. As shown in the note to Table 7-3, the recommended specifications imply a capacity of up to 1068 transactions per scan. (This does not include ELMs. ELMs are discussed in the next section.)

An important question at this point is whether the beam dwell transaction capacity written in Table 7-3 can be physically achieved by the DABS system, subject to the basic constraints of radio propagation delays of the DABS signals. Appendix C shows actual scheduling of these peak requirements. It proves that these peak requirements are, in fact, physically achievable.

### 7.1.5 Extended Length Messages (ELMs)

This study incorporates a minimal use of uplink ELMs. Downlink ELMs were not found to be necessary to support the services assumed in this study. However, this should not be construed as a recommendation that downlink ELMs be eliminated from the DABS concept. The results summarized so far have a significance in terms of establishing minimum DABS avionics options. It must be realized that uplink and downlink ELMs do provide the most important vehicle for future expansion of data link usage. The U. S. DABS National Standard (Reference 3) establishes upper limits on total uplink messages from a DABS sensor. These are summarized in Table 7-6. It is recommended that the sensor ELM capacity be designed to be consistent with the U.S. DABS National Standard.

TABLE 7-4

SAMPLE HISTOGRAMS OF PEAK MULTIPLE TRANSACTIONS WITHIN 90° QUADRANTS

| Sensor | Total Number of Aircraft in a 90° Quadrant | | Total Number of Transactions in Quadrant | Number of Aircraft Receiving N Transactions Where N = | | | | | | | | | Number of Aircraft Transmitting N Comm-Bs Where N = | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | Total | DABS | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 0 | 1 | 2 | 3 | 4 |
| SNA | 219 | 175 | 344 | 44 | 111 | 19 | 15 | 11 | 12 | 4 | 2 | 1 | 182 | 24 | 10 | 3 | 0 |
| ONT | 128 | 105 | 261 | 23 | 53 | 12 | 13 | 10 | 6 | 5 | 3 | 3 | 103 | 12 | 12 | 1 | 0 |
| LAX(1) | 255 | 202 | 406 | 53 | 99 | 45 | 32 | 13 | 10 | 2 | 1 | 0 | 219 | 26 | 10 | 0 | 0 |
| LAX(1) | 250 | 195 | 402 | 55 | 88 | 48 | 34 | 13 | 9 | 2 | 1 | 0 | 213 | 27 | 9 | 0 | 1 |

(1) These two LAX peaks are not disjoint; rather, an 80° azimuthal section is common to the two. They are both listed here because they show slightly different types of peaking.

TABLE 7-5

HISTOGRAMS OF MULTIPLE TRANSACTIONS FOR SENSORS
(FOR ENTIRE 360° SCAN)

| Sensor | | Number of Aircraft | | Total Number of Trans-actions | Number of Aircraft Receiving N Transactions Where N = | | | | | | | | | Number of Aircraft Trans-mitting N Comm-Bs Where N = | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | Failing Sensor | Total | DABS | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 0 | 1 | 2 | 3 | 4 |
| LGB | 2 | 394 | 310 | 536 | 84 | 202 | 42 | 35 | 16 | 10 | 4 | 1 | 0 | 346 | 33 | 14 | 1 | 0 |
| SNA | 3 | 411 | 323 | 582 | 88 | 209 | 43 | 30 | 19 | 15 | 4 | 2 | 1 | 354 | 38 | 16 | 3 | 0 |
| ONT | 4 | 376 | 306 | 678 | 70 | 146 | 62 | 38 | 30 | 16 | 7 | 4 | 3 | 315 | 43 | 16 | 2 | 0 |
| SBD | 3 | 273 | 222 | 449 | 51 | 102 | 62 | 27 | 20 | 6 | 3 | 2 | 0 | 234 | 32 | 7 | 0 | 0 |
| VFV | 6 | 375 | 313 | 456 | 62 | 218 | 63 | 21 | 6 | 5 | 0 | 0 | 0 | 327 | 39 | 7 | 2 | 0 |
| PMD | 5 | 375 | 313 | 456 | 62 | 218 | 63 | 21 | 6 | 5 | 0 | 0 | 0 | 327 | 39 | 7 | 2 | 0 |
| BUR | 8 | 325 | 255 | 544 | 70 | 105 | 69 | 46 | 19 | 10 | 5 | 1 | 0 | 273 | 39 | 12 | 0 | 1 |
| LAX | 7 | 509 | 389 | 676 | 120 | 234 | 75 | 49 | 15 | 12 | 3 | 1 | 0 | 449 | 44 | 15 | 0 | 1 |

TABLE 7-6

UPPER LIMITS OF INTERROGATION RATES FOR DABS(1)

| Scan Angle | Time Duration | Maximum Uplink Message Rate Per Second Averaged Over The Time Duration | Implied Maximum Number of Interrogations Within the Time Duration(2) |
|---|---|---|---|
| 360° | 4 Sec | 1165 | 4660 |
| 90° | 1 Sec | 1840 | 1840(3) |
| 3.6° | 40 Millisec | 2400 | 96(4) |

(1) From Reference 3 (U.S. DABS National Standard).
(2) These include uplink ELM segments.
(3) This is based on an assumption of 40 ELMs in 90°. See Appendix D.3.
(4) This implies 64 uplink messages in 2.4°

The recommended peak standard transaction requirements for a beam dwell amount to only 48 uplinks (Table 7-3) whereas Table 7-6 shows an allowance of up to 64 uplinks in a 2.4° beam dwell. Thus, there is room for 16 more uplink messages in a beam dwell. One 16-segment uplink ELM within the peak beam dwell could therefore be accommodated within the DABS National Standard constraints.

The U.S. DABS National Standard, in developing its interrogation rate limits, assumes that up to 40 uplink ELMs may be transmitted in a 90° quadrant. (See Table 7-6.) It is therefore recommended that the sensor be designed to transmit 40 uplink ELMs in the peak quadrant.

Even though no use is seen of downlink ELMs in the near future, the capability to schedule and process them should be included in the DABS sensor specifications.

### 7.1.6 Synchronous Transactions

One synchronous transaction per scan is sufficient for a target. Note that a target must first receive a normal surveillance transaction in a beam dwell to be able to receive a synchronous transaction later in that beam dwell.

### 7.1.7 Miscellaneous

DABS sensor capability to schedule messages is a function of the maximum target range and target distribution over that range. Appendix C shows that the peak beam dwell requirements specified in this chapter are physically realizable for a range of 50 nmi. At significantly longer ranges, the same sensor may not be able to deliver such performance, purely due to the limitations caused by propagation delays. For the sake of accurate specifications, and for the sake of realizable testing procedures, a maximum range of 50 nmi should be specified in capacity specifications. This maximum range is specified only for the purpose of testing and benchmarking the capabilities of the sensor. It does not imply that a DABS sensor should not or can not service targets farther than 50 nmi.

## 7.2 Recommended Specifications

This section contains a formal data link capacity specification intended for possible direct use in a technical DABS procurement specification. Table 7-7 summarizes the recommended specifications. They apply to DABS sensors of all capacities (250 targets, 400 targets or 700 targets). Table 7-7 shows data

TABLE 7-7

RECOMMENDED DABS DATA LINK CAPACITY REQUIREMENTS

| Type of Peaking | Number of Targets (DABS & ATCRBS) | Number of Aircraft Receiving N Comm-As Where N = | | | Number of Aircraft Transmitting N Long Replies Where N = | | | | Number of Aircraft Receiving 16 Segment Uplink ELMs (1) | Number of Aircraft Transmitting 16 Segment Downlink ELMs |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 4 | 8 | 1 | 2 | 3 | 4 | | |
| 2.4° Beam Dwell | 15 | 4 | 5 | 3 | 3 | 2 | 1 | 1 | 1 | 0 |
| 11.25° Sector | 50 | 18 | 20 | 6 | 8 | 4 | 2 | 2 | 8 | 3 |
| 90° Quadrant | 250 | 90 | 85 | 25 | 32 | 16 | 8 | 8 | 40 | 15 |

(1) Uplink ELM numbers are derived from the U.S. DABS National Standard maximum uplink message rate limits. (Reference 3; see Table 7-6.)

(2) Only DABS aircraft receive the data link messages summarized in this table. Each ATCRBS aircraft receives four ATCRBS surveillance interrogations each scan.

link transaction requirements under various peak target loading conditions. These requirements are based on the analysis documented in this study. Sensors which satisfy these requirements will, with a proper deployment configuration, be able to deliver all the services discussed in this study in the densest air traffic DABS may encounter in its life time. The study includes reinterrogation requirements for messages. The discussion presented in Section 7.1 justifies each number in Table 7-7 in detail. It should be pointed out that although the formats of ATARS/BCAS coordination assumed in the computer analyses were the now obsolete CIR formats, the impact of the current RAR concept on these results has been thoroughly investigated wherever a significant sensor performance specification was involved (for example, the requirement to deliver eight Comm-As). These revisions have been incorporated in the recommended specifications. In other words, the recommendations presented in this section reflect the use of the RAR concept for ATARS/BCAS coordination. The extent of the use of uplink ELMs is governed by the maximum number of messages consistent with the upper limits placed by the DABS National Standard.

Section 7.2.1 contains the formal specifications.

### 7.2.1 The Formal Recommended Capacity Specifications for the DABS Sensor

The sensors to be fabricated shall be designed to handle a total of 250, 400 or 700 aircraft. The design shall be capable of being altered simply (by the addition or removal of computer hardware and software modules) in order to accommodate 250, 400 or 700 aircraft. The capacity requirements stated in this section shall be achieved when four ATCRBS/All-Call intervals are provided within the 3 db antenna beam width.

The aircraft will not necessarily be distributed uniformly in azimuth or in range. Bunching may result in more targets in some sectors than the average. The sensors shall be designed to handle the following cases of azimuthal bunching. The following requirements shall be met regardless of the range distribution of the targets involved for any range distribution within a range of 0 to 50 nmi from the sensor.

Quadrant Peaking: The 250 aircraft, the 400 aircraft, and the 700 aircraft sensors shall handle 250 aircraft uniformly distributed by azimuth in a 90° quadrant. 25 DABS aircraft uniformly distributed by azimuth within a quadrant shall each be able to be interrogated eight times per scan for surveillance or Comm-A delivery. Of these eight interrogations, one may be synchronous. An additional 85 DABS aircraft uniformly distributed by azimuth within a quadrant shall each be able to be interrogated four times per scan for surveillance or Comm-A interrogations, out of which one may be synchronous. The remaining DABS aircraft shall be able to be interrogated once per scan for surveillance or Comm-A delivery. The sensor shall be able to interrogate for Comm-B replies from DABS aircraft as follows: eight aircraft shall each be able to be interrogated for four Comm-B replies per scan, another eight shall be able to be interrogated for three Comm-B replies each per scan, another 16 shall be able to be interrogated for two Comm-B replies each per scan and another 32 shall be able to be interrogated for one Comm-B reply each per scan. 40 DABS aircraft uniformly distributed by azimuth within a quadrant shall each be able to be interrogated for one uplink ELM of 16 segments per scan. Fifteen DABS aircraft uniformly distributed by azimuth within a quadrant shall each be able to be interrogated for one downlink ELM transmission of 16 segments per scan.

Sector Peaking: The 250 aircraft, the 400 aircraft, and the 700 aircraft sensors shall handle a short term peak of 50 aircraft uniformly distributed by azimuth in an 11.25° sector for four consecutive sectors. Six DABS aircraft uniformly distributed by azimuth within each of the four sectors shall be able to be interrogated eight times each per scan for surveillance or Comm-A delivery. Out of these eight interrogations one may be synchronous. An additional 20 DABS aircraft uniformly distributed by azimuth within each of the four sectors shall be able to be interrogated four times each per scan for surveillance or Comm-A interrogations, out of which one may be synchronous. The remaining DABS aircraft shall each be able to be interrogated once per scan for surveillance or Comm-A delivery. The sensor shall be able to interrogate for Comm-B replies from these DABS aircraft as follows: two aircraft shall be able to be interrogated for four Comm-B replies each per scan, another two shall each be able to be interrogated for three Comm-B replies per scan, another four shall be able to be interrogated for two Comm-B replies each per scan and another eight shall be able to be interrogated for one Comm-B reply each per scan. Eight DABS aircraft uniformly distributed by azimuth within each of the four sectors shall each be able to be interrogated for one uplink ELM of 16 segments per scan. Three DABS aircraft uniformly distributed by azimuth within each of the four sectors shall each be able to be interrogated for one downlink ELM transmission of 16 segments per scan.

Beam Dwell Peaking: The 250 aircraft, the 400 aircraft, and the 700 aircraft sensors shall handle a shorter term peak of 15 aircraft uniformly distributed by azimuth in a 2.4° beam dwell for two consecutive beam dwells. Three DABS aircraft within each of the two beam dwells shall be able to be interrogated eight times each per scan for surveillance or Comm-A delivery. Of these eight interrogations one may be synchronous. An additional five DABS aircraft in each of the two beam dwells shall be able to be interrogated four times each per scan for surveillance or Comm-A interrogations, out of which one may be synchronous. The remaining DABS aircraft shall be able to be interrogated once each per scan for surveillance or Comm-A delivery. The sensor shall be able to interrogate for Comm-B replies from DABS aircraft as follows: One aircraft shall be able to be interrogated for four Comm-B replies per scan, another (one) shall be able to be interrogated for three Comm-B replies each per scan, two others shall be able to be interrogated for two Comm-B replies each per scan and three shall be able to be interrogated for one Comm-B reply per scan each. One DABS aircraft within each of the two beam dwells shall be able to be interrogated for one uplink ELM of 16 segments per scan. The final Comm-C/Comm-D transaction for this uplink ELM should be counted as one of the (equivalent) Comm-A/Comm-B transactions specified earlier. There is no downlink ELM requirement under the peak beam dwell conditions.

When the sensor is not under the above stated peak target loading conditions during a particular beam dwell, sector or a quadrant, it should be capable of scheduling the maximum number of ELMs such that the total number of uplink messages (Comm-As and Comm-Cs) in that beam dwell, sector or a quadrant are equal to those found in the respective peak loading conditions for beam dwells, sectors or quadrants as described above. However, the total uplink message rate should not exceed 4660 interrogations in one radar scan.

## 7-· Comparison of Three DABS Capacity Specifications

Appendix D, Section D.1, contains the capacity specifications written in 1974 (Reference 14) for the DABS engineering models. Section D.2 contains the specifications written in April 1980 by the Systems Research and Development Service of the FAA for possible procurement of DABS production models (Reference 15). Table 7-8 shows a comparison of these specifications with those recommended here in Section 7.2.1. Some major points in Table 7-8 are noted in the following paragraphs.

TABLE 7-8

A COMPARISON OF THREE DABS CAPACITY SPECIFICATIONS

| Type of Peaking | Specification Type(1) | Specifications: Number of Aircraft Receiving N Comm-As Where N = | | | | | Number of Aircraft Transmitting N Comm-Bs Where N = | | | | Number of Aircraft Receiving 16 Segment Uplink ELMs | Number of Aircraft Transmitting 16 Segment Downlink ELMs | Total Number of Aircraft in Azimuth | Resulting Message Rates: Total Number of Comm-As | Total Number of Comm-Cs | Total Uplink Message Volume | DABS National Standard (Upper Limits for Uplink Messages) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 8 | 1 | 2 | 3 | 4 | | | | | | | |
| 2.4° Beam Dwell | 1974 ER | | 32 | | | | Not Specified | | | | 0 | 0 | 32 | 64 | 0 | 64 | 64 |
| | 1980 ER | | 32 | | | | Not Specified | | | | 0 | 0 | 32 | 64 | 0 | 64 | |
| | Recommended | 4 | | | 5 | 3 | 3 | 2 | 1 | 1 | 1 | 0 | 15 | 48 | 15(2) | 63 | |
| 11.25° Sector | 1974 ER | | | 50 | | | Not Specified | | | | 3 | 3 | 50 | 150 | 48 | 198 | Not Specified |
| | 1980 ER | | | 45 | | 5 | Not Specified | | | | 3 | 3 | 50 | 175 | 48 | 223 | |
| | Recommended | 18 | | | 20 | 6 | 8 | 4 | 2 | 2 | 8 | 3 | 50 | 146 | 128 | 274 | |
| 90° Quadrant (for 400 Aircraft Sensor | 1974 ER | | | 400 | | | Not Specified | | | | 24 | 24 | 400 | 1200 | 384 | 1584 | 1840 |
| | 1980 ER | | | 360 | | 40 | Not Specified | | | | 24 | 24 | 400 | 1400 | 384 | 1784 | |
| | Recommended | 90 | | | 85 | 25 | 32 | 16 | 8 | 8 | 40 | 15 | 250 | 630 | 640 | 1270 | |

(1) 1974 ER = FAA-ER-240-26, November 1974, Reference 14
1980 ER = FAA-ER-240-26A, April 1980, Reference 15
Recommended = The specifications described in Section 7.2.1
(2) The final Comm-C/Comm-D transaction of the ELM in peak beam dwell is counted as one of the standard Comm-A/Comm-B transactions.

Peak target loading specifications in References 14 and 15 are too high for beam dwells and quadrants. Peak target loading specifications for sectors are the same for all three specifications (50 aircraft per sector).

The specifications recommended here require fewer Comm-As in a beam dwell. Appendix C shows that the recommended beam dwell capacity is consistent with the physical limits of the DABS channel. References 14 and 15 make no specifications regarding Comm-B messages. However, with a comparable number of Comm-B messages in a beam dwell, the peak capacity required by References 14 and 15 seems to approach the idealized maximum DABS channel capacity (see Appendix C).

The 1980 ER (Reference 15) provides for the necessary maximum eight Comm-A requirement. However, its provisions may not be sufficient. Table 7-4 shows that for the Ontario sensor, 60 aircraft out of its total of 376 aircraft, i.e., 16% of its aircraft, require more than three transactions each. Reference 15 provides for only 10% of its aircraft (i.e., a maximum of 40 aircraft for a 400 aircraft sensor) to receive eight transactions each.

The recommended specifications guarantee as many ELMs as possible within the constraints imposed by the DABS National Standard. The ELM capacity provided by the other two specifications is considerably lower.

The recommended specifications guarantee an uplink ELM in a peak beam dwell. With some modifications in the priority scheme, this may provide for the use of ELMs for priority services such as ATC. The other two specifications do not guarantee uplink ELM delivery during peak beam dwells.

All three specifications are within the limits of uplink messages established by the DABS National Standard (Reference 3). Recommended specifications are also consistent with the duty factor specifications of Reference 15, excerpted in Section D.4.

It should be noted that such differences between the specifications recommended in this study and the other two specifications discussed here is to be expected because the specifications recommended here are based on a detailed analysis of a revised traffic model and more information available about the nature and formats of the possible uses of the data link.

## 7.4 Data Link Message Storage Requirements

The recommended specifications imply a maximum of 1068 Comm-A messages and a maximum of 4660 uplink messages (Comm-As plus Comm-Cs) per radar scan for a 400 aircraft sensor. The services assumed in this study show the use of only about four ELMs per scan for a 400 aircraft sensor. The remaining uplink message capacity reflects DABS growth potential through uplink ELMs. It is recommended that DABS message storage capacity be 1200 messages, expandable in multiples of 1200 messages up to a maximum of 4800.

It should be noted that the actual use of Comm-As and Comm-Cs as presented in the analysis so far is less than 1200 messages. Table 5-4 shows at most 678 transactions for a sensor (ONT). Since 90 of these are surveillance transactions and there could be about four ELMs in a scan, this shows a total uplink volume of about 650 (678-90+64 = 652) messages for that sensor. About 250 of these are from sources different from ATARS. DABS message storage capacity specification however should not be tied to those lower actual utilization numbers. Specifying a sensor with less message storage capacity than its maximum data link transaction capacity will imply placing an arbitrary smaller limit (equal to the message storage capacity) on the sensor data link capacity. This will imply utilizing the specified sensor at a considerably lower capacity than what it is capable of.

## 7.5 ATARS Processing

The ATARS function collocated with DABS processes aircraft pairs for generation of advisories. A filtering subfunction called the coarse screen is used to identify pairs of aircraft to be processed more thoroughly for generating traffic advisories. The number of aircraft pairs out of the coarse screen function are therefore useful for identifying total ATARS processing requirements. Table 7-9 provides these numbers for the three Los Angeles models for the entire basin; they are not available for each site separately. The numbers are provided for the nominal coarse screen parameters of Reference 5 as well as a slightly reduced (more realistic) parameter set.

The maximum number of aircraft in the seams for any sensor is 224. The maximum number of aircraft within 10 nmi of a sensor (i.e., within the so-called zenith sector) is 87.

TABLE 7-9

NUMBER OF AIRCRAFT PAIRS OUT OF ATARS COARSE SCREEN

| Model | Nominal Parameters[1] | Reduced Parameters |
|---|---|---|
| | TLV = 120 sec, RMAXV = 5 nmi<br>TLI = 75 sec, RMAXI = 8 nmi | TLV = 60 sec, RMAXV = 4 nmi<br>TLI = 60 sec, RMAXI = 4 nmi |
| LAX-1840 | 25078 | 15108 |
| LAX-1100 | 9350 | 5431 |
| LAX-600 | 2709 | (not available) |

(1) As per Reference 5

# 8. DABS GROWTH POTENTIAL

The requirements of Section 7 were obtained on the basis of considering the need for delivering the set of services described in Chapter 3 in a projected high density future environment. The question arises: How much more capacity does DABS have? Can DABS support more services or more traffic than that assumed in this study? Section 8.1 discusses the use of ELMs for accommodating major new services. This is illustrated by demonstrating the feasibility of providing fine grain weather radar data via the DABS data link. Section 8.2 summarizes the total percent usage of DABS in providing all the services discussed in this study, including the provision of fine grain weather radar data. Thus, Section 8.2 also shows the capacity left over in the system under the worst loading conditions discussed here. Finally, Section 8.3 shows the inherent expansion potential of DABS under any loading conditions through the deployment of additional sensors.

## 8.1 High Resolution Weather Radar Data

The set of services considered in the main part of this study includes digitized weather radar data with a coarse grain (22 nmi X 22 nmi grid). (See Chapter 3.) Weather radar data with such resolution is useful for flight planning purposes. However, there is considerable interest in the user community for tactical hazardous weather avoidance. This would require weather data with considerably finer resolution. WSR-57 weather radar data is suitable for this service since that radar has a $2^{\circ}$ beamwidth and a $\pm$ 0.5% range accuracy over its maximum operating range of 250 nmi (Reference 16). This implies a range accuracy $\pm$ 1.25 nmi for its data. Thus, at 50 nmi from a WSR-57 sensor, the weather is known to an accuracy of 1.75 nmi X 2.5 nmi.

Assume that a single static digitized weather radar picture is provided to the pilot in an X-Y grid on request. The pilot has two options as shown in Table 8-1. With six intensity levels per cell, either option implies nearly 50,000 bits of information. Reference 17 shows that an average data compression by a factor of five can be attained by data reduction techniques for this type of data. Thus, a full picture may be transmitted in 9830 bits. One 16 segment ELM can transfer 1280 bits. Thus, the entire picture can be transmitted in eight ELMs.

Even under peak target and transaction loading considerations, the recommended specifications of Section 7.2 allow one ELM per beam dwell. (It is conceivable that more than one ELM may be

TABLE 8-1

PILOT OPTIONS FOR HIGH RESOLUTION WEATHER RADAR DATA

| Option | Area | Resolution | Number of Intensity Levels | Total Number of Bits Per Picture |
|---|---|---|---|---|
| 1 | 256 nmi x 256 nmi | 2 nmi | 6 (3 Bits) | 49152 |
| 2 | 128 nmi x 128 nmi | 1 nmi | 6 (3 Bits) | 49152 |

uplinked under sub-peak conditions.) If one aircraft in the peak beam is requesting a weather picture, he would receive a complete picture in at most eight scans or about half a minute after its request.

It is of interest to identify the worst possible delay for providing such a service. Assume that bad weather prompts all 12 DABS equipped aircraft in the peak beam to request digitized high resolution weather radar data. This would require a total of 96 ELMs to transmit in one beam. Assuming all requests come at once, a total of about six minutes would be required for transmitting 96 ELMs. The last aircraft would thus receive the picture six minutes after its request. Others would receive it earlier. The average delay would be three minutes.

It should be realized that this is the worst possible case of such delay. The average beam contains only about two DABS aircraft. Thus, the delay in receiving a picture would usually be no more than one minute after requesting it. Further, not every aircraft in a beam is likely to request weather radar data at the same time. Finally, in bad weather, there will very likely be fewer aircraft in the airspace than that assumed in this worst traffic density model. There will therefore be fewer requesting aircraft and hence smaller delays in receiving the data.

The average uplink ELM message rate per scan due to this service is a function of the overall frequency of weather requests. Assume that each one of the 320 DABS equipped aircraft in the nominal sensor's jurisdiction (80% of its 400 targets) request a picture about once in 15 minutes. The sensor would thus be required to uplink a total of 2560 uplink ELMs in 15 minutes. This gives an average rate of (2560/15) * 1/15 = 11.4 uplink ELMs per scan or 182 Comm-Cs per scan.

Services described earlier in Chapter 3 make a very meager use of ELMs. Occasionally (about once in one hundred scans) there is an ELM required for those other services. In such an event, a processor called an "application processor" (which accepts all non-ATC and non-ATARS data link messages for presentation to the DABS sensor) would queue the messages for delivery, possibly resulting in one extra scan of delay for the digitized high resolution weather radar data, or some delay for the other service. The uplink ELM rate for the sensor would be maintained at design levels.

In summary, the DABS system can effectively provide a high resolution weather radar data service to each aircraft in its jurisdiction. Since avionics such as a printer or a cathode ray tube display may already exist in the cockpit for other uses, such a service may be available to the user at a very low extra cost.

## 8.2 Percent Capacity Utilization

The beam dwell is the most basic unit of delivering DABS data link service. Table 8-2 shows the heaviest possible usage within a beam dwell as seen in this study and compares it to the DABS capacity specifications for beam dwells. Note that delivery of high resolution weather radar data is also included in peak utilization. Comm-Bs are included in this table, since they become important when the percentage of time line utilization is under scrutiny. The peak beam dwell in LAX-1100 contains 29 transactions, seven of which require Comm-B replies. (See Table 5-5.) DABS specifications allow about 64 Comm-A and Comm-B transactions. Thus, as shown in the table, under peak loading conditions, about 60% of DABS capacity is being used. The specifications recommended here guarantee the uplinking of one ELM even in a peak beam dwell. The specifications of Reference 15 do not guarantee the uplinking of an ELM when there are 64 transactions to be scheduled in a beam dwell. However, with only 29 + 7 = 36 Comm-A and Comm-Bs to be transacted, a sensor satisfying 1980 ER specifications is also expected to be able to accommodate an ELM. Thus, even under peak loading conditions, there is considerable room for providing additional services beyond those assumed in this study.

Theoretical DABS time line capacity is also indicated in Table 8-2. At full time line capacity, there exist trade offs between times occupied by Comm-As, Comm-Bs and ELMs. It is clear, however, that the utilization is well within the maximum ideal channel capacity.

## 8.3 Percent Utilization with Respect to the U.S. DABS National Standard

Table 8-2 shows that the maximum number of uplink messages in a beam dwell is 45. The maximum uplink message rate for a 2.4° beam dwell established by Reference 3 is 64. Thus, the peak uplink message rate presented by the heaviest data link activity (in a peak beam dwell) in LAX-1100 while providing all the services discussed in this study is 70% of the maximum acceptable peak rate.

It is expected that the main growth of services provided by DABS beyond those presented in this study would be in the realm of

TABLE 8-2

COMPARISON OF DATA LINK UTILIZATION IN PEAK BEAM DWELL WITH PEAK CAPACITY

| | Standard Transactions | | | ELMs[1] | Total Standard Trans-actions | Total Uplink Message Volume | Comments |
|---|---|---|---|---|---|---|---|
| | Comm-A | Comm-B | Comm-A & Comm-B | | | | |
| Total Peak Beam Dwell Utilization | 29 | 7 | 36 | 1 | 38 | 45 | a. Includes all services in main study plus high resolution weather radar data<br>b. 29 + 16 = 45 |
| Recommended Peak Beam Dwell Specifications | 48 | 14 | 62 | 1 | 62 | 63 | a. Final Comm-C/Comm-D is included in the Comm-A/Comm-B specifications<br>b. 48 + 15 = 63 |
| 1980 ER Specifications (Reference 15) | 64 | ? | ? | 0 | 64 | 64 | |
| Theoretical Time Line Capacity | 72 | 0 | 72 | 0 | 72 | 72 | 18 Comm-As per DABS period[2] |
| | or 48 | 48 | 96 | 0 | 96 | 48 | 12 Comm-A/Comm-Bs per DABS period[2] |
| | or 60 | 12 | 72 | 2 | 72 | 90 | 2 DABS periods with 18 Comm-As each + 1 DABS period with 12 Comm-A/Comm-Bs[3] + 1 DABS period with 12 Comm-As and 30 Comm-Cs |
| DABS National Standard | | | | | | 64 | |

(1) An ELM consists of 15 Comm-C segments and a final Comm-C/Comm-D transaction. This final transaction is a standard transaction, just like a Comm-A/Comm-B transaction (as far as the scheduler is concerned).
(2) See Figures C-2 and C-4.
(3) Actually 10 Comm-A/Comm-Bs and 2 Comm-C/Comm-Ds for the two ELMs.

low priority services, i.e., services which could accept some scan to scan delay in delivery. Under peak loading conditions, low priority services could, if necessary, be delayed for delivery to later scans, when the beam dwell loading conditions change due to the movement of traffic. Thus additional services could be provided without ever having to exceed peak beam dwell uplink message limits. Statistically speaking, such future additional services would increase the total uplink message volume per scan. It is therefore of interest to estimate the extent to which more uplink messages could be transmitted by DABS without exceeding total (per scan) DABS National Standard limits.

Table 8-3 summarizes the highest DABS data link utilization per scan as presented in this study and compares it to the maximum allowed message rates in the DABS National Standard (Reference 3). All the services put together (including high resolution weather radar data) require a total of 678 standard transactions and 15 ELMs per scan for the most heavily loaded sensor, giving a total uplink message volume of 918. This is within 20% of the maximum allowable uplink message rate (4660) established by Reference 3. Clearly, there is considerable room for additional services as far as the U.S. DABS National Standard limits are concerned.

The maximum total uplink message volume for a sensor presented in Reference 1 was 866. However, Reference 1 did not consider uplinking high resolution weather radar data. This is the reason why the total uplink message volume in this study (918) is slightly greater than that presented in Reference 1.

## 8.4 Expansion of DABS Capacity

Inherent in the DABS capacity specifications is a provision for an easy expansion of target capacity from 250 to 400 to 700 targets. (See Section 7.2.1.) Thus, if target densities in an area should increase, sensor capacities may be boosted as necessary.

Once the limits of expansion of an individual sensor is reached, further traffic growth or more demand for data link may be accommodated by deployment of additional sensors in the region. The availability of more capacity per target by the deployment of additional neighboring sensors can best be understood by understanding Figure C-2. Figure C-2 shows the variation of DABS transaction capacity per target as a function of target numbers and their maximum range. It shows that a DABS sensor can transact a larger number of messages per aircraft in a beam

TABLE 8-3

COMPARISON OF TOTAL SENSOR UTILIZATION AND DABS NATIONAL STANDARD LIMITS

| | Total Number of Standard Transactions Per Scan | Total Number of ELMs Per Scan | Total Uplink Interrogations Per Scan | Comments |
|---|---|---|---|---|
| Total Utilization | 678(1) | 15 | 918 | Worst Sensor For Standard Messages, About 12 ELMs For High Resolution Weather Radar Data & 3 ELMs For all Other Services |
| DABS National Standard | | | 4660(2) | |

(1) See Table 7-5.
(2) See Table 7-6.

dwell as (1) either the beam dwell target load decreases or (2) the range over which the targets in the beam are distributed decreases. Thus, whereas a sensor can transmit four Comm-As to each target for 12 targets in a beam distributed over 90 nmi, it can transmit eight Comm-As (i.e., twice the previous number) to each target for nine targets in a beam distributed over 50 nmi. The deployment of a neighboring sensor accomplishes both these effects. The new sensor would be deployed so as to share the densest traffic areas. This would reduce the maximum number of targets to be served as well as the service range for these targets in that area. Thus the saturating sensor is off-loaded and available data link capacity to aircraft in the dense areas is actually increased.

DABS sensors are thus analogous to communication channels. When, due to an increase in demand, existing channels (i.e., sensors) begin to get saturated, additional sensors can be provided to meet this increase in demand.

The deployment of a new sensor in any existing ATC environment, of course, requires exercising many site specific judgments. Before a new sensor is deployed, studies should be conducted to guarantee that the deployment of a new sensor would maintain the airspace free of unacceptable radio frequency interference.

# APPENDIX A

## THE LAX-1100 MODEL

This Appendix describes the nominal air traffic model called LAX-1100 used in this study. LAX-1100 is derived from an existing and previously widely used traffic model of the 1995 Los Angeles hub described in Reference 9, here referred to as LAX-1840. LAX-1840 makes extensive use of real life information about the Los Angeles basin such as airport locations, terrain, likely airspace and route restrictions, traffic flows and patterns, aircraft altitude and speed profiles appropriate to their performance categories and flight types, and so on. The model was hand made. All this renders the model quite realistic as far as aircraft spatial distributions are concerned. However, the traffic levels used for building the model were based on the forecasts available in 1972. Air traffic projections have since experienced a significantly slower rate of growth as a result of the energy crisis. The LAX-1100 model incorporates the latest FAA forecasts. It is based on the LAX-1840 model and maintains all the realism otherwise inherent in that model. Section A.1 briefly summarizes the relevant methodology of the original LAX-1840 model. Section A.2 summarizes the new forecasts used for revising LAX-1840. Section A.3 describes the method used for obtaining LAX-1100. Section A.4 describes the method used for obtaining LAX-600, the low density model used in the sensitivity study in Chapter 7.

### A.1 Review of LAX-1840 Methodology

Reference 9 uses the growth in the total annual operations in the Los Angeles hub to estimate the growth in the peak instantaneous airborne count (IAC) in the basin. Let N71 and N95 be the peak instantaneous airborne counts for the Los Angeles hub in 1971 and 1995 respectively. Let A71 and A95 be the total annual operations in the Los Angeles hub for 1971 and 1995 respectively. Then, Reference 9 assumes that

$$\frac{N95}{N71} = \frac{A95}{A71}$$

Reference 13 provides a peak IAC of 495 for the base year (actually 1972). Reference 18 shows that this IAC is based on about 82% of the air traffic activity in the entire basin. Thus, the total basin IAC, N71 was estimated by Reference 9 to be 600. The 1971 annual operations count (A71 = 6,357,000) operations was available from FAA sources. The 1995 operations count, A95, was obtained by the following method:

$$A95 = (1+R)^{24} * A71, \text{ where R is given by } (1+R)^{10} = A83/A73$$

A83 and A73 were obtained from FAA Terminal Area forecasts (see Reference 9 for details). This gives A95 = 19,477,000. Therefore N95 = (19477/6357) * 600 = 1840. This total IAC of 1840 was then subdivided into various subgroups in proportion to component operation numbers.

## A.2 New Forecast

Reference 19, published in 1978, provides FAA forecasts of air traffic in the Los Angeles hub for years up to 1990. Table A-1 lists these forecasts for the years 1985 and 1990 for three types of operations: air carriers, general aviation itinerant, and general aviation local. This is the finest subdivision of operations available in Reference 19. For this study, the operations within each category were projected another five years, to the year 1995, assuming a constant yearly percent growth between 1985 and 1995. These resulting new forecasts for 1995 are also listed in Table A-1.

Table A-2 compares these new forecasts to the original 1995 forecasts used in deriving LAX-1840. Military operations are assumed to remain constant at the levels of Reference 9. Table A-2 shows the ratio of the new forecasts to the old forecasts for each flight category. The new forecast yields a total annual operations count which is about 60% of the old forecast. Thus, maintaining the methodology used in Reference 10, the total number of aircraft in the 1995 Los Angeles basin peak snapshot would be expected to be about 60% of the number in LAX-1840.

## A.3 Derivation of LAX-1100

Since Reference 9 assumes a proportionality of the growth in annual operations to peak IAC at all levels, the new forecasts should be reflected in smaller total IAC's for the basin in each of the three flight categories of Table A-2 in the proporations listed there. A random number generator is used to delete aircraft from the LAX-1840 model, as shown in Figure A-1. The final set of aircraft in the output file LAX-NEW is thus a proper subset of the aircraft in LAX-1840. Each aircraft that is retained in LAX-NEW has all its original coordinate values.

Three different runs were made, with three different starting random number seeds providing three different LAX-NEW models. The three versions had 1074, 1096 and 1105 aircraft respectively. Of the three versions the one with 1105 aircraft had the most conflicts (68) and also had five multi-aircraft conflicts. The other versions had no multi-aircraft conflicts. Therefore, being the worst of the three versions in all respects, the 1105 aircraft model was chosen as the revised Los Angeles basin model and was named LAX-1100.

TABLE A-1

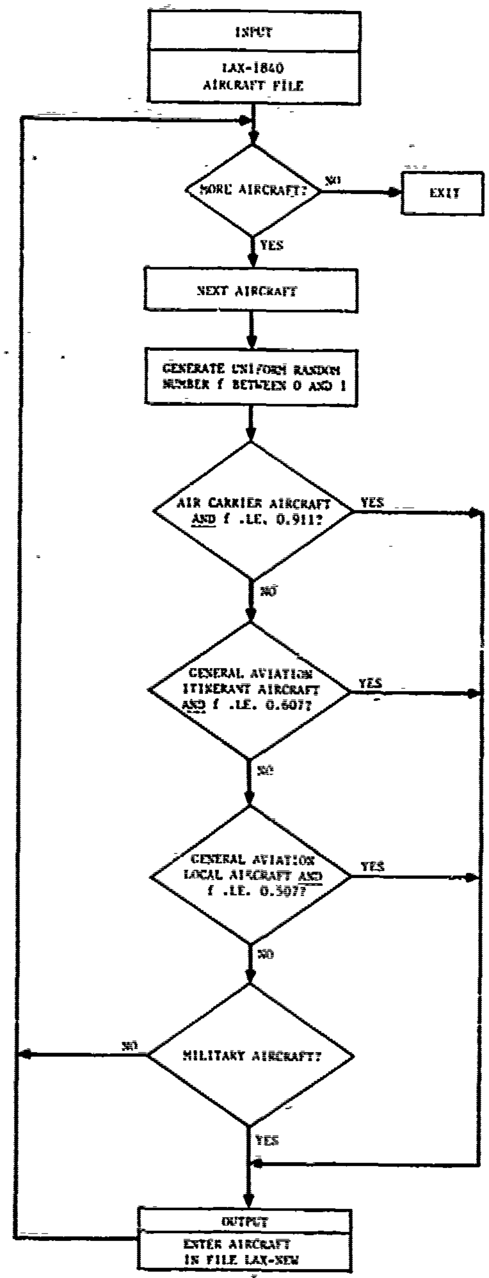
1978 AVIATION FORECASTS FOR THE L.A. HUB

| Type of Projection | Forecast For Year | Air Carriers | General Aviation | |
|---|---|---|---|---|
| | | | Itinerant | Local |
| FAA (Reference 19) | 1985 | 840 | 4317 | 3676 |
| | 1990 | 1014 | 4825 | 4060 |
| Geometric Projection | 1995 | 1224 | 5393 | 4484 |

TABLE A-2

COMPARISON OF FORECASTS

| | (Annual Operations in Thousands) | | | | |
|---|---|---|---|---|---|
| | Air Carriers | General Aviation Itinerant | General Aviation Local | Military | Total |
| New 1995 Forecast (From Table A-1) | 1224 | 5393 | 4484 | 409 | 11510 |
| Old 1995 Forecast (From Tables 3-2 and 3-4 of Reference 9) | 1344 | 8882 | 8842 | 409 | 19477 |
| Scaling Factor | 0.911 | 0.607 | 0.507 | 1 | |




NOTE: .LE. = LESS THAN OR EQUAL TO

**FIGURE A-1**
**GENERATION OF LAX-1100**

LAX-1100 data formats are described in Reference 20. LAX-1100 is stored on Tape Number 1218 at the MITRE/Washington Computing Center Tape Library.

## A.4 Generation of LAX-600

The low density model was also generated from LAX-1840 in the same fashion except each scaling factor (for each of the user categories) was simply further multiplied by the factor (600/1100). For example, the scaling factor used for air carriers was

$$(600/1100) * 0.911 = 0.498$$

The resulting model has 580 aircraft and is called LAX-600. This model is stored on Tape Number 1219. Its formats are identical to those of LAX-1100.

## A.5 Storage of LAX-1840

LAX-1840 is stored on Tape Number 1220. Its formats are identical to those of LAX-1100. (This supersedes previous storage and format information regarding this model reported in Reference 9.)

# APPENDIX B

## AVIONICS EQUIPAGE

This appendix provides the scheme mentioned in Section 5.1 to classify aircraft in the LAX-1100 model so that classification in that model becomes consistent with national fleet projections of the DABS Transition Plan (Reference 10).

### B.1 DABS Transponder Equipage

According to the DABS Transition Plan, all but the low-performance (i.e., single engine) general aviation fleet becomes completely equipped with DABS transponders, whereas 71.9% of the single-engine fleet becomes DABS-equipped. This translates into 22.5% of the total air carrier and general aviation (GA) population being unequipped. (See Reference 1.)

The LAX-1100 model contains a total of 1105 aircraft. Of these, 1066 are air carriers and GA. Thus, .225 x 1066 = 240 of these would be unequipped. All these would be single engine aircraft. There are a total of 748 single engine aircraft in the model. Thus, 240/748 = 32% of the single engine aircraft in the LAX-1100 model should be assigned "unequipped" status. Actually, 31.6% were assigned "unequipped" status, due to the use of aircraft counts from another version of LAX-1100.

### B.2 Downlink of Airborne Data

All but the single engine general aviation aircraft are assumed to be equipped with avionics for gathering airborne data (airspeed, heading, etc.) and providing it to the transponder. According to the Transition Plan, 20.3% of all aircraft fall into this category. Thus, 216 out of the total of 1105 aircraft in LAX-1100 should be so equipped. Table B-1 provides an appropriate mapping by aircraft-type for such a classification.

### B.3 ATC Services

ATC messages are issued to IFR aircraft and controlled VFR aircraft. The LAX-1100 model does not indicate controlled status (e.g., within the TCA) for VFR aircraft. The total percentage of aircraft receiving ATC services was therefore obtained from Reference 11. IFR and controlled VFR aircraft form 43.8% of the total aircraft population in the model used in Reference 11. Use of this percentage in the LAX-1100 model yields a total of 484 aircraft under ATC control. Of these, 215 are IFR aircraft. Thus 269 VFR

TABLE B-1

SCHEME FOR ASSIGNING THE CAPABILITY
TO DOWNLINK AIRBORNE DATA

| LAX-1100 Class of Aircraft | Total Number in LAX-1100 Model | % Assigned to Downlink Airborne Data | Number of Aircraft Eligible to Downlink Airborne Data |
|---|---|---|---|
| Air Carriers | 119 | 100% | 119 |
| Non-Air-Carrier Turbine, Jet and Heavy Multi-Engines | 44 | 100% | 44 |
| Light Multi-Engines (Less Than 12500 lbs) | 151 | 35% | 53 |
| Total | --- | --- | 216 |

aircraft in the LAX-1100 model are assumed to be controlled. All VFR itinerant multi engine and turbine powered aircraft and 59% of all VFR itinerant single engine aircraft with more than three places are assumed to be controlled for this purpose.

It may be noted that the controlled status of these VFR aircraft is not carried into the ATARS algorithms being executed on the model. ATARS gives a preferred treatment to "controlled" aircraft. Only the nearly 15% of the aircraft that exist as IFR aircraft in the LAX-1100 model are treated as these preferred "controlled" aircraft in the ATARS algorithms in this study.

## APPENDIX C

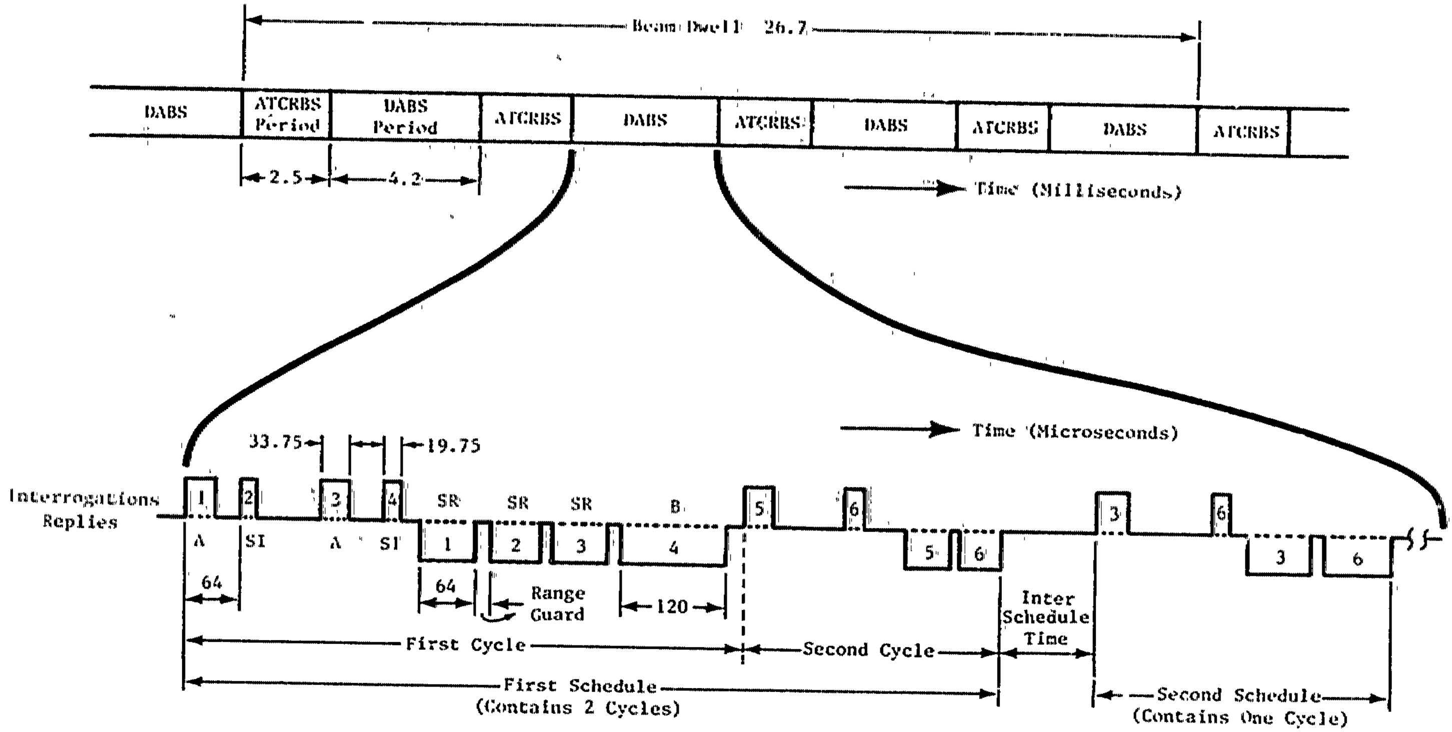
## TIME LINE ANALYSIS

This section provides an analysis of the theoretical DABS channel time line. Section C.1 provides an idealized analysis of the capacity of the DABS in terms of transactions in a beam dwell. Section C.2 shows examples of actually scheduling the peak beam dwell requirements specified in Section 7.2.

### C.1 Time Line Channel Capacity

Reference 1 describes the DABS message scheduling process in detail. Figure C-1, taken from Reference 1 shows the scheduling process at a glance. The beam dwell of 26.7 milliseconds results from a 4 sec antenna scan rate for a $2.4^{o}$ 3 db beam width. There are four DABS periods in each beam dwell, each of length 4.175 milliseconds. The number of transactions that can be scheduled in a DABS period is dependent upon the number of targets in the beam, their distribution over the range, the types of transactions and their distribution over the targets, the value of the range guard parameter and the scheduler overhead appearing here as the inter-schedule time. The inter-schedule time is dependent upon the amount of processing that the scheduler (especially the reply processor) must do between schedules, and the available computing power. The amount of processing is, in part, dependent upon the validity of the replies from the previous schedule. "Computing power" includes the speed of computation, memory and buffer sizes, and the efficiency of the software. In the history of the DABS engineering model specifications, the specified value for this parameter (inter schedule time) has experienced a great deal of variation, and it continues to be discussed at the time of writing this document. However, it is of the order of 100 microseconds in all specifications. In addition, some DABS engineering models have been known to use some time at the beginning and end of a DABS period for computational purposes. Clearly, under these circumstances, the full DABS period is not available for scheduling messages. However, it is useful to obtain an indication of the maximum possible message transaction capacity of the DABS time line under assumptions of minimal wastage of the channel time for computational purposes.

Figure C-2 shows the capacity of the DABS time line in terms of Comm-A transactions per aircraft per scan (i.e., per beam dwell) as a function of the number of targets in a beam. This computation assumes a "static" beam, i.e., assuming that the same given number of targets are available throughout the beam dwell for each DABS




Numbers 1, 2, ......, 6 Correspond To Targets

A = COM[illegible] Interrogation

B = COMM-B Reply

SI = Surveillance Interrogation

SR = Surveillance Reply

**FIGURE C-1**
**TIME LINE DEPICTION OF DABS SCHEDULING**

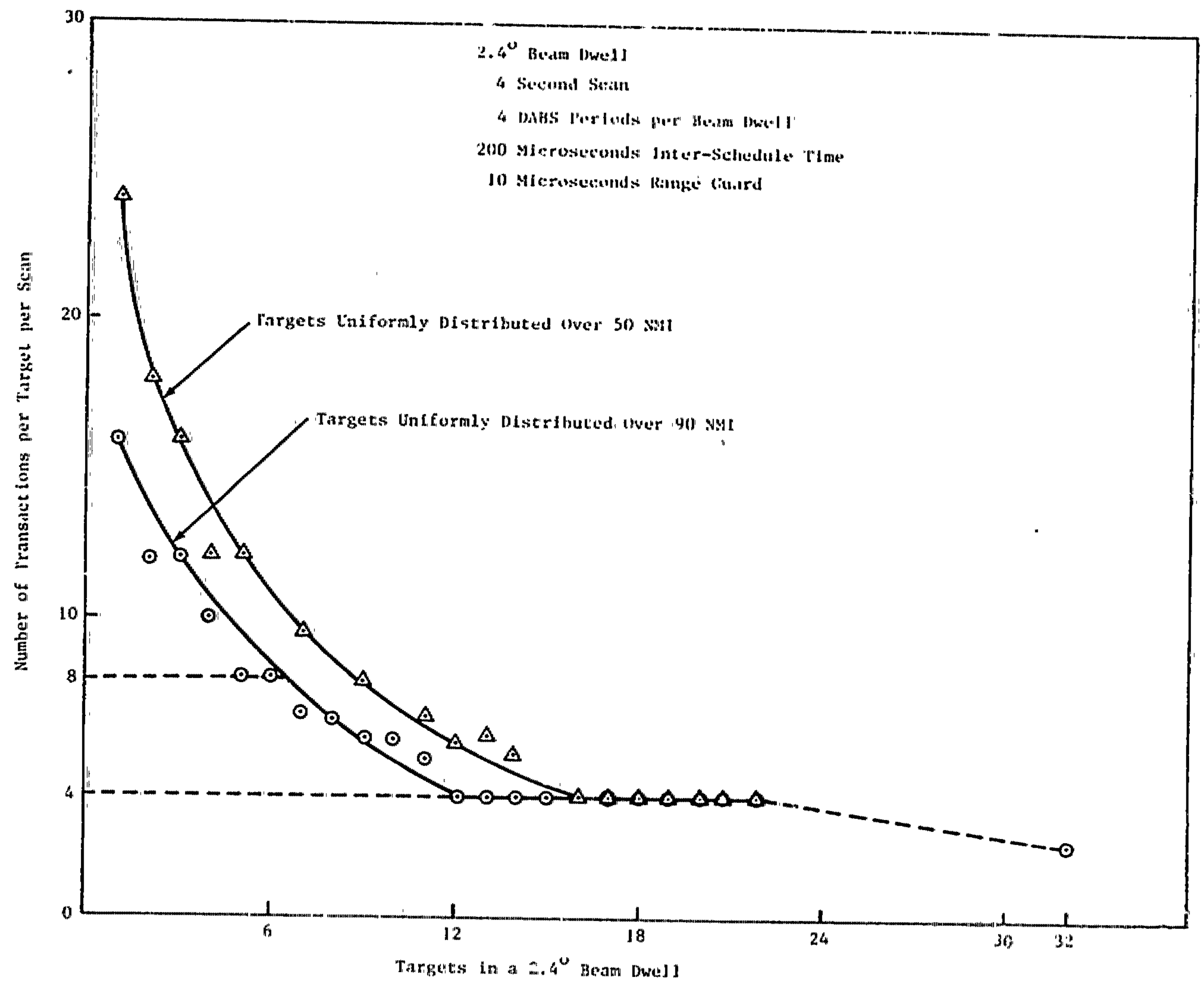



**FIGURE C-2**
**COMM-A TRANSACTIONS PER AIRCRAFT PER SCAN**

period. It assumes a four second antenna rate, a 2.4° beam dwell, a 10 microsecond range guard value and a 200 microsecond inter-schedule time between any two schedules. The entire 4.175 millisecond DABS period is assumed to be available for scheduling. The computations assume a 132 microsecond transponder delay. (NOTE: The transponder delay time has since been established at 128 microseconds.) Targets are assumed to be distributed uniformly over the assumed maximum range. (Uniform target distribution is assumed since such a distribution provides the worst case situation as far as the scheduling algorithm is concerned. If, for example, all targets are assumed to be at any one particular range, more transactions can be scheduled.) Each transaction consists of a Comm-A interrogation and a surveillance reply. The counts shown are a result of transactions actually scheduled for each beam dwell. Sometimes, although there is some time left over at the end of a period, it is not sufficient to schedule the next target. If there is room to schedule the first m targets of the total of n targets in one beam, the next DABS period is assumed to start by scheduling the next (n-m) targets. Then a fresh schedule starts again. Targets are always scheduled in decreasing range order. If there are a total of T transactions schedule in the beam, Figure C-2 shows an average of (T/n) transactions per target for that number (n) of targets. It is seen that for more targets in a beam, each target receives fewer Comm-As. This Comm-A capacity per target also usually increases with a reduction in range. For up to 22 targets in a beam, each target can receive at least four Comm-As. Beyond 22 targets, the average number for each reduces to lower values, being an average of 2.6 Comm-As to each of 32 targets distributed uniformly over 90 nmi.

It should be noted here that the average number of transactions per aircraft are presented here purely for the sake of demonstrating the sensitivity of the data link capacity to the maximum target range and the total target count in the beam dwell. There is no implication here that the sensor should or would send an equal number of messages to each target. This is neither necessary nor useful. From the sensor's point of view, the total number of transactions within a beam dwell is a very useful descriptor. Such a description is provided in Figure C-3. It shows the results of the same scheduling exercise in the form of the total number of Comm-A transactions within a beam dwell. Thus, for 12 targets in a beam, the sensor can schedule a total of 48 transactions if the maximum range is 90 nmi. It can schedule a total of 78 transactions if the maximum range is 50 nmi. The most capacity that can be expected from the DABS channel time line is about 90 transactions. It is, however, dependent upon the number of targets in a beam and the maximum range.

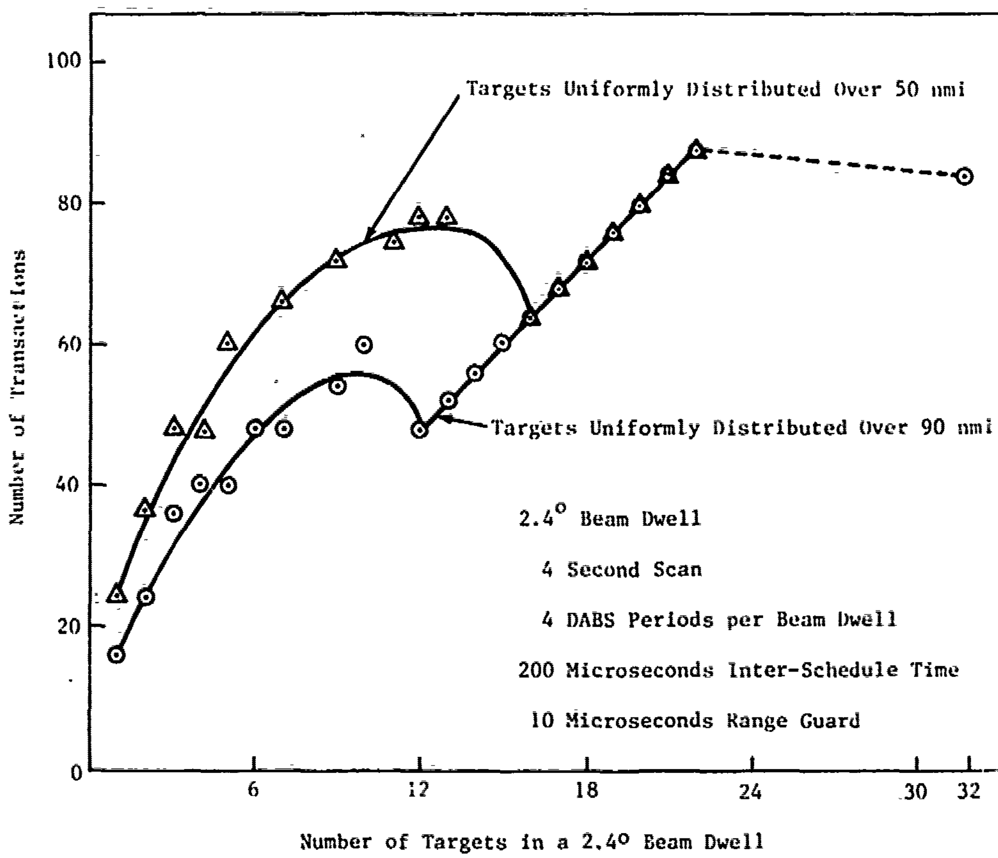



**FIGURE C-3**
**TOTAL COMM-A TRANSACTIONS PER BEAM DWELL AS A FUNCTION OF NUMBER OF TARGETS IN A BEAM**

Below about four or five targets in the beam, there aren't enough targets to fill up all the channel time between the first interrogation and the first reply of a schedule. In other words, channel time is being used up purely because of the propagation delay. Smaller target loads also contribute several inter-schedule times since there are several schedules each period. Finally, for any target load, there is a third type of unused time within each period, which cannot be used for forming a new schedule (or a cycle) because it is shorter than the round trip propagation time of the target to be scheduled next. (This is the highest range target in the case of a new schedule. It can be a target with a lower range in the case of a new cycle.) During this time where no standard transaction scheduling is done, ELM segments could be scheduled. (In the actual time line sequence, ELM segments are scheduled in the beginning of the DABS period and the standard transactions are scheduled during the latter part of the DABS period.)

The loss of channel time due to inter-target range delay is larger for 90 nmi than for 50 nmi, for the same number of targets. This is why the 50 nmi case usually yields more channel capacity.

Figure C-4 shows the number of Comm-A/Comm-B transactions that can be scheduled within the DABS time line. All the parameters of these computations are the same as those for Figure C-2. The only difference here is that each transaction consists of a Comm-A interrogation and a Comm-B reply. Since the Comm-B reply is 120 microseconds, (56 microseconds longer than the surveillance reply) these transactions use more time in the time line. For nine targets in a beam, there is sufficient time to schedule four Comm-A/Comm-B transactions to each target, for a 90 nmi range. This should be compared to the six Comm-A transactions to each target at the same range for the same number of targets (Figure C-2). For 12 targets in a beam, four Comm-A/Comm-B transactions can be scheduled to each target for either range.

## C.2 Scheduling the Peak Requirements

Figure C-5 shows two examples of actually scheduling the peak beam dwell requirements of Section 7.2. The DABS time line is shown in microseconds. Each DABS period is 4175 microseconds long. Each example shows aircraft scheduled over four DABS periods. The table adjoining each time line shows 12 aircraft, distributed uniformly over 50 nmi and the messages (Comm-A, Comm-B and ELMs) required to be transacted with each. The final Comm-C/Comm-D segment of an ELM is to be counted as a Comm-A/Comm-B transaction according to Section 7.2, and is included in the Comm-A/Comm-B requirements. The assumed

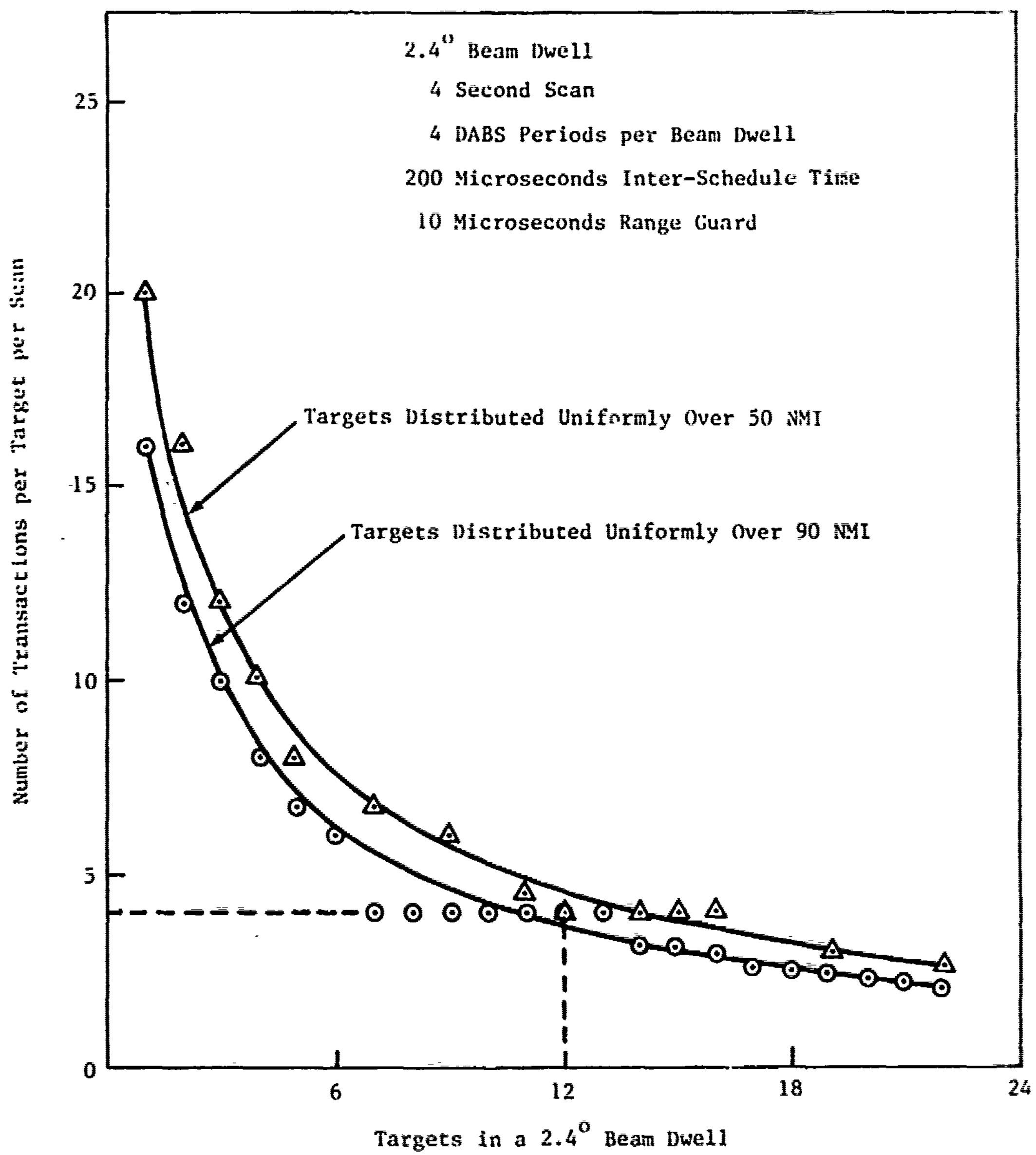
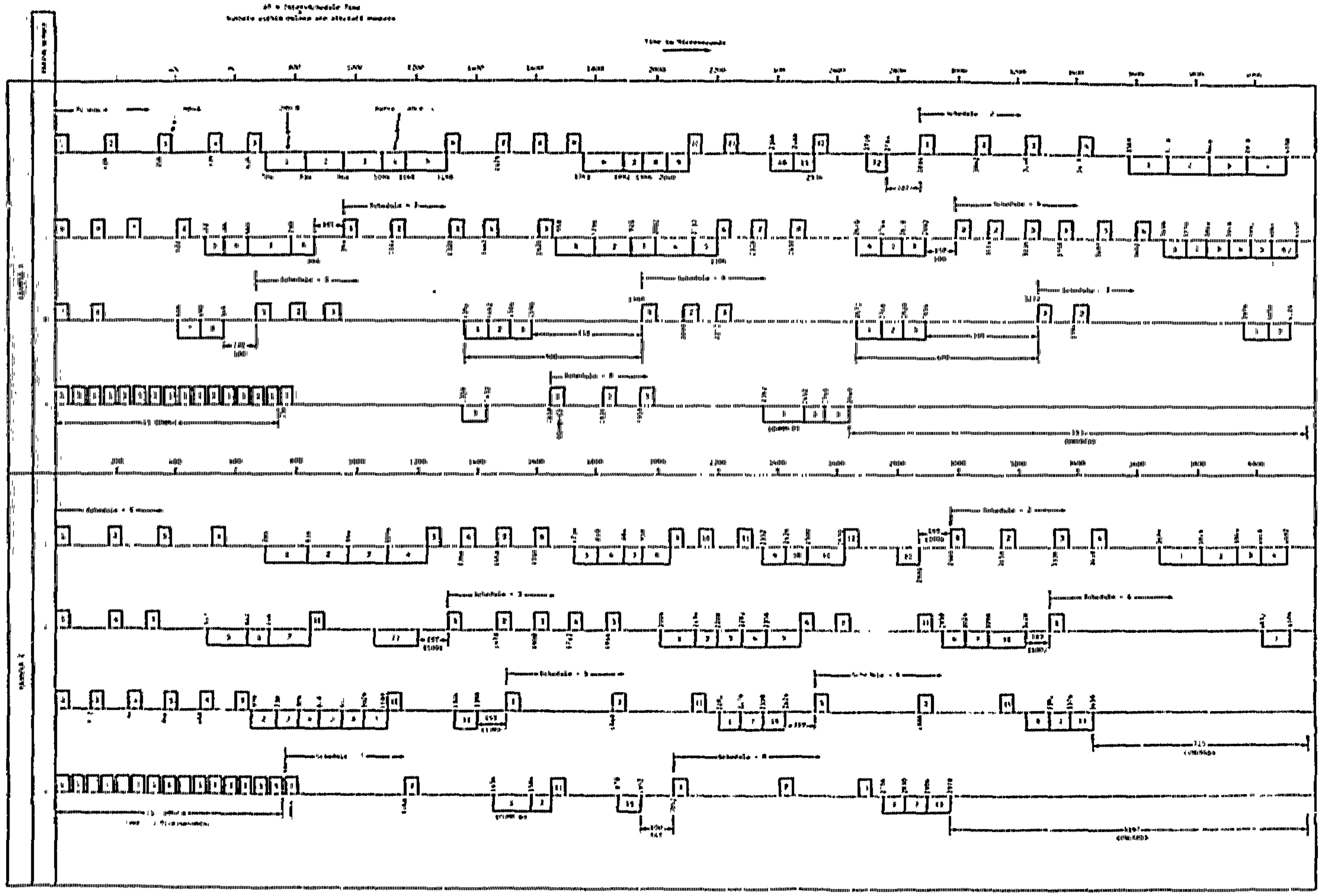



**FIGURE C-4**
**COMM-A/B TRANSACTIONS PER AIRCRAFT PER SCAN**




Scenario 1

| Aircraft Number | Range in NMI | Change = [illegible] Microseconds | DMPM-A | | | | | | | | DMPM-B | | | | Optional DMPM-C | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 48 | 396 | A | A | A | A | A | A | A | A | B | B | B | B | [illegible] | (1) |
| 2 | 44 | [illegible] | A | A | A | A | A | A | A | A | | B | B | B | | |
| 3 | 40 | [illegible] | A | A | A | A | A | A | A | A | | | B | B | | |
| 4 | 36 | 360 | | | | | A | A | A | A | | B | B | (1) | | (2) |
| 5 | 32 | [illegible] | | | | | A | A | A | A | | | | B | | |
| 6 | 28 | 464 | | | | | A | A | A | A | | | | B | | |
| 7 | 24 | 416 | | | | | A | A | A | | | (3) | B | (3) | | (3) |
| 8 | 20 | 368 | | | | | A | A | A | A | | | | | | |
| 9 | 16 | 320 | | | | | | | | A | | | | | | |
| 10 | 12 | 272 | | | | | | | | A | | | | | | |
| 11 | 8 | 224 | | | | | | | | A | | | | | | |
| 12 | 4 | 176 | | | | | | | | A | | | | | | |

Scenario 2

| Aircraft Number | Range in NMI | Change = [illegible] Microseconds | DMPM-A | | | | | | | | DMPM-B | | | | Optional DMPM-C | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 48 | 396 | A | A | A | A | A | A | A | A | B | B | B | B | [illegible] | (1) |
| 2 | 44 | [illegible] | | | | | A | A | A | A | | | B | B | | |
| 3 | 40 | [illegible] | | | | | A | A | A | A | | | | B | | |
| 4 | 36 | 360 | | | | | A | A | A | A | | | | B | | |
| 5 | 32 | 312 | | | | | A | A | A | A | | B | B | (2) | | (2) |
| 6 | 28 | [illegible] | | | | | A | A | A | A | | | | | | |
| 7 | 24 | 416 | A | A | A | A | A | A | A | A | | (3) | B | (3) | | (3) |
| 8 | 20 | 368 | | | | | | | | A | | | | | | |
| 9 | 16 | 320 | | | | | | | | A | | | | | | |
| 10 | 12 | 272 | | | | | | | | A | | | | | | |
| 11 | 8 | 224 | A | A | A | A | A | A | A | A | | B | B | B | | |
| 12 | 4 | 176 | | | | | | | | A | | | | | | |

COMMENTS:

(1) [illegible]

(2) [illegible]

(3) [illegible]

FIGURE C-4
TWO EXAMPLES OF SCHEDULING PLUS BEAM DWELL REQUIREMENTS

messages incorporate one pilot initiated Comm-B downlink and an example of a CIR transfer where the first transaction involves a surveillance downlink. The RDLY parameter = 12 * Range + 128 microseconds.

The schedules are mostly self explanatory. Interschedule times of 100 microseconds are usually used, as per specifications in Reference 15. Processing delays in the reply processor are simulated by allowing at least 600 microseconds after a reply to an interrogation to the same aircraft. For example, in DABS period number 3 (first example), the inter-schedule time is nearly 400 microseconds so that aircraft number 1 may not be interrogated less than 600 microseconds after its last reply. Both examples show over 1200 microseconds unused time in the last period. (Actually, the last 725 microseconds in the third schedule of example 2 is also unused and could be used for Comm-C segments. Thus, the unused time in example 2 is nearly 2000 microseconds.) Thus, about 90% of the time line is being used for these schedules.

These examples have been chosen to represent some of the worst possible cases of scheduling the peak requirements of Section 7.2. Further, considerable allowance for processing of replies has been made. Thus, it is seen that the peak requirements recommended in Section 7.2 can be accommodated in the time line.

It should finally be pointed out that these schedules assume a 4-second scan time for the DABS antenna. Current DABS engineering models utilize a 4.7 second scan time, which provides for a 31.3 millisecond beam dwell (2.4°). This implies 21.3 millisecond for DABS scheduling, nearly 30% more than the 16.7 millisecond assumed in this analysis. For such an antenna, the peak schedules described here would fit in nearly 70% of the total beam dwell, rather than using nearly 90% of the time as in these examples.

## APPENDIX D

## SOME RELEVANT SPECIFICATIONS

In this appendix is collected some reference material for ready use in Chapter 7. Section D.1 contains the DABS capacity requirements as written in November 1974 (Reference 14). Section D.2 shows DABS capacity requirements as written in April 1980 (Reference 15). Section D.3 shows peak uplink message rates from the U. S. DABS National Standard (Reference 3). Section D.4 shows duty factor specifications for the DABS sensor (Reference 15).

### D.1 DABS Capacity Specifications from Reference 14 (Section 3.3.2.5)

The sensors to be fabricated shall be designed to handle a total of 400 aircraft containing any mix of DABS, ATCRBS, and radar targets. The targets will not necessarily be distributed uniformly in azimuth. Rather, bunching may result in more targets in some sectors than the average. The sensor shall be designed to handle the following cases:

(a) A peak of 50 aircraft in an 11-1/4$^{o}$ sector, for not more than eight consecutive sectors. Each aircraft in each sector shall be able to be interrogated up to three times for surveillance, synchronization, Comm-A or Comm-B delivery. In addition, three of the aircraft in each sector shall be able to send and three shall be able to receive an Extended Length Message (ELM) of up to 16 segments.

(b) A short-term peak of 16 aircraft in a 1.2$^{o}$ azimuth wedge for up to three contiguous wedges. It shall be possible to interrogate each aircraft in each such wedge up to two times for surveillance, synchronization or Comm-A or Comm-B delivery. ELM messages need not be handled during this short term peak situation.

(c) A communications load each scan as follows:

Comm-A for 50% of the total number of tracks
Comm-B for 10% of the total number of tracks

(d) At any time, the sensor shall be able to provide or receive remote sensor data on up to 15% of the tracks in the sensor track file. In addition the sensor shall be able to accommodate the failure and recovery of up to two adjacent sensors.

The above stated capacity shall be achieved when four ATCRBS/All-Call intervals are provided within the 3 dB antenna beamwidth.

In addition, the design shall incorporate a growth capability in such a way that the computer hardware and software could be directly and economically expanded to accommodate 700 aircraft, in steps of 100 aircraft. The sector peak as defined in (a) shall be expanded to 90 aircraft (with five uplink and five downlink ELMs of up to 16 segments) under the same bunching and interrogation loading as described therein. The short-term peak requirement shall remain the same as previously specified. The contractor shall produce a design study to show how this expansion would be performed and to demonstrate through analysis thac this increased capacity could be obtained economically, as a prerequisite for seeking CDR approval for implementation of the basic design choices.

## D.2 DABS Capacity Specifications from Reference 15 (Section 3.3.2.5)

The sensors to be fabricated shall be designed to handle a total of 250, 400 or 700 aircraft containing any mix of DABS, ATCRBS, and radar targets. The targets will not necessarily be distributed uniformly in azimuth. Rather, bunching may result in more targets in some sectors than the average. The 250 and 400 aircraft sensors shall be designed to handle the following cases:

(a) A peak of 50 aircraft uniformly distributed in an 11.25 degree sector for not more than five or eight consecutive sectors for the 250 and 400 aircraft cases respectively. Each aircraft in each sector shall be able to be interrogated up to three times for surveillance, synchronication, Comm-A or Comm-B delivery. It shall be possible to interrogate 10% of these aircraft an additional five times for Comm-A/Comm-B activity necessary to support ATARS coordination. In addition, three of the aircraft in each sector shall be able to send, and three shall be able to receive, an Extended Length Message (ELM) of up to 16 segments.

(b) A short-term peak of 16 aircraft in a $1.2^{o}$ azimuth wedge for up to three contiguous wedges. It shall be possible to interrogate each aircraft in each such wedge up to two times for surveillance, synchronization or Comm-A or Comm-B delivery. ELM messages need not be handled during this short term peak situation.

(c) A communications load each scan as follows:

Comm-A for 50% of the total number of tracks
Comm-B for 10% of the total number of tracks

(d) At any time, the sensor shall be able to provide or receive remote sensor data on up to 15% of the tracks in the sensor track file. In addition the sensor shall be able to accommodate the failure and recovery of up to two adjacent sensors.

The above stated capacity shall be achieved when four ATCRBS/All-Call intervals are provided within the 3 dB antenna beamwidth.

In addition, the design shall be capable of being altered simply (by the addition or removal of computer hardware and software modules) in order to accommodate 250, 400 or 700 aircraft.

When configured to handle 700 aircraft the peak sector loading shall not exceed the loading defined in (a) with the traffic distributed over 16 sectors. The short-term peak requirement shall remain the same as previously specified.

## D.3 Limits of DABS Uplink Messages from Reference 3 (Section 6.1.3) Repetition Rate for Discrete Interrogations

The interrogation rate for DABS uplink formats is:

(a) less than 1165 per second averaged over a 4 second interval

(b) less than 1840 per second averaged over a 1 second interval

(c) less than 2400 per second averaged over a 40 millisecond interval.

Note: The interrogation rate above depends on the number of DABS transponders within the coverage volume of the interrogator. If there are no DABS transponders in this volume, the interrogation rate is zero. The rates given above are based on the following assumptions considering absolute worst-case traffic loading and bunching for a rotating antenna interrogator with a four second/360° scan rate:

| Scan Angle: | Number of DABS Aircraft | Interrogations Per Aircraft | | Total Number of Interrogations | Period | Rate (Per Sec) |
|---|---|---|---|---|---|---|
| 360° | 700 | 3 Long | | 2,100 | | |
| | +160 | 16 ELM | | 2,560 | | |
| | | | Total | 4,660 | 4 Sec | 1,165 |
| 90° | 400 | 3 Long | | 1,200 | | |
| | + 40 | 16 ELM | | 640 | | |
| | | | Total | 1,840 | 1 Sec | 1,840 |
| 3.6° | 48 | 2 Long | | 96 | 0.04 Sec | 2,400 |

## D.4 Duty Factor Specifications from Reference 15 (Section 3.4.2.3.1.1)

Power output and duty factor: In the high-power mode the primary transmitter shall produce a peak power of up to 800 watts and a long-term average power of up to 15.4 watts both referred to the sensor RF port. The averaging time requirements for the high-power mode are as follows. In the high-power mode the transmitter shall be capable of initiating:

(a) at least one long (112-bit) DABS interrogation in any 50-microsec interval,

(b) but not to exceed 24 long DABS interrogations in any 4-msec interval,

(c) but not to exceed 60 long DABS interrogations in any 100-msec interval.

In the low-power mode the primary transmitter shall produce a peak power of up to 200 watts, and a long-term average power of up to 7.6 watts both referred to the sensor RF port. The averaging time requirements for the low-power mode are as follows. In the low-power mode the transmitter shall be capable of initiating:

(a) at least one long (112-bit) DABS interrogation in any 50-microsec interval,

(b) no more than 32 long DABS interrogations in any 2-msec interval,

(c) no more than 96 long DABS interrogations in any 40-msec interval,

(d) no more than 3440 long DABS interrogations in any 2-sec interval,

(e) no more than 4720 long DABS interrogations in any 4-sec interval.

In addition to the DABS interrogation rates specified above, the transmitter shall be capable of transmitting ATCRBS/DABS or ATCRBS Only All-Call interrogations at a uniform rate of up to 150 per second at either of the two specified power levels.

APPENDIX E

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